WATER REQUIREMENTS FOR THE FISHERIES RESOURCE OF THE NANAIMO RIVER

Canada

Department of the Environment

Fisheries and Marine Service

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Introduction

The Greater Nanaimo Water District is planning to construct a dam on Jump Creek, a tributary of the South Fork of the Nanaimo River, to provide an additional storage capacity of 1.5 to 2.5 billion gallons for their primary water supply. This dam would be upstream of their present dam and reservoir which was built in 1931.

This report describes the ways in which reduced river flows affect the salmon resource, the effects of the present major diversions and the need for establishment of satisfactory dry weather flows. Specific recommendations are made pertaining to control of and releases of water from the Nanaimo reservoir system. These recommendations are derived from hydrological data and numerous observations by biologists and fisheries' officers over the years.

Basin Hydrology and Development

The Nanaimo River, on the east coast of Vancouver Island, flows easterly, from its origin at an altitude of approximately 5,000 feet, some 35 miles to its mouth at the south end of Nanaimo Harbour (Fig. 1). It has a total drainage area of about 320 square miles. The average annual precipitation varies from 30 inches at the mouth to 60 inches at the headwaters.

Flow records were first taken at the hydrographic station 08HB005 near Extension which operated from 1913 to 1927 and from 1948 to 1964, measuring flow from a drainage area of 249 square miles. A newer station, 08HB034 near Cassidy, with a drainage area of 264 square miles has been operating since 1965. The maximum daily discharge up to 1970 was 44,000 C.F.S. on January 15, 1961 and the minimum was 28.7 C.F.S. on September 5, 1951, a ratio of 1,500 to 1. The annual average discharge rate is 1,430 C.F.S.

Hydrographs for the driest years on record (1923, 1924, 1925, 1926, 1951, 1952) covering the months July to November are shown in Figs. A1 to A6, Appendix A.

A station has also been operating at the mouth of Jump Creek on the South Nanaimo River since November 1970.

The average monthly flows are shown on Fig. 2 and Fig. 3 lists the main water licences on Nanaimo River. The major users are MacMillan and Bloedel Ltd. and the City of Nanaimo. M & B have licences totalling 125 cfs. on the Nanaimo River and in addition, another licence for 35 cfs. on the Haslam Creek, a major tributary. Haslam Creek is fully recorded except for domestic licences. There are a number of other minor licences on Nanaimo River, mainly for domestic use.

In 1931, the City of Nanaimo constructed a 100 foot high concrete dam on the South Nanaimo River with a reported storage capacity of 1,660 acre feet for their water supply. There was no provision made for releases through the dam except that there is a leakage of approximately 2 cfs. through the blocked off diversion tunnel. During the wet winter months, there will be spill over the crest but during the dry late summer and early fall months the reservoir level normally drops below the crest cutting off all flow into the river except the leakage flow.

Although the drainage area to the dam is 30% of the drainage area to the Nanaimo River, the proportion of run-off as calculated from Jump Creek records is 43 percent. This difference can be explained by the differential elevations and rainfalls within the watershed. A value of 35% has been selected as a conservative compromise of the above values for use in calculations which follow .

A report prepared in 1970 by Associated Engineering Services Ltd. for the Greater Nanaimo Water District recommends an additional dam on Jump Creek by the year 1976 to impound 1.5 million to 2.5 million gallons. The lower figure would represent a quantity sufficient for Greater Nanaimo until the year 2,000, when it is estimated that the demand will be 6.2 mgd., whereas the larger volume would be necessary if a regional plan were to be adopted. The regional study of 1972 by the same consultant points to the South Fork-Jump Creek watershed as being the prime source of water.

In 1954 MacMillan and Bloedel Ltd. built a dam at Fourth Lake to store water for their Harmac operation. The reservoir has a reported capacity of 28,000 acre feet with a drainage area of 11 square miles.

During low flow periods water is released into the main river from the reservoir to augment the flow for withdrawal down river at their pumping station just below the Island Highway. The discharge record from 1954 to 1962 as prepared by M & B is included as Figure B1. M & B are required by the terms of their water licence to leave a minimum flow of 39 cfs. in the river below their intakes. For this purpose they have installed a staff gauge approximately 1/2 mile below the pumphouse. Their rating curve for the gauge is included as Figure B2.

The Fisheries Resource

Nanaimo River is considered as one of British Columbia's best rivers for steelhead angling and an important producer of salmon. All five species of Pacific salmon(chum, coho, chinook, pink, and sockeye) have, in the past, been reported to occur in the river but in recent years the numbers of pink and sockeye have declined to where only the occasional one is found. There has also been a general trend downward for the other species as shown by the bar graphs, Figures 5 to 7. A manuscript report by K. V. Aro of the Pacific Biological Station in Nanaimo summarizes the Salmon and Trout resource of the river. Parts of his report are reproduced below (see also Figures 2 and 4):

Chum

Chum salmon spawn in the Nanaimo River from its confluence with the Chase River upstream as far as Haslam Creek. Most of the spawning takes place in the main channel up to and adjacent to Indian Reserve No. 3 and above the Cedar Road Bridge in Polkinghorne's Slough and Side Channel and in Maffeo's Side Channel. Some chum also spawn in the lower reaches of

Haslam Creek. Returning chum salmon begin arriving in the river from late August to late September. Spawning commences shortly after arrival in the stream, reaches a peak in mid to late October, and ends by late November or early December.

Coho

Earlier running coho spawn in the Nanaimo River and its tributaries upstream as far as Second Lake. Later running coho spawn in the lower part of the river in the same areas as do the chum. As mentioned earlier, some coho spawn also in Chase River and in Hong Kong and Holden Creeks. Coho commence arriving in the river in late August and in September. Spawning takes place from late September to late December or early January with the peak in late October, early November.

Chinook

The Nanaimo River chinook run has spring and fall components. The spring chinook enter the river from early April to late June and spawn in the Nanaimo River below First Lake. The fall chinook enter the river in late August and September and spawn in the river below the Trans Canada Highway Bridge downstream as far as Cedar. Generally, spawning commences in September, reaches a peak in October and ends in November and December.

Pink

In the fifties, small mumbers of pink salmon were reported in the Nanaimo River in both even and odd numbered years. None have been reported since 1960. The pinks spawned in the lower 3 miles of the Nanaimo River and lower quarter mile of Haslam Creek.

Sockeye

Since 1949, sockeye salmon have been reported in the Nanaimo River in 1951, 1957, and 1958. These sockeye either were strays from other river systems, or were the descendants of sockeye which may have resulted from the introduction of eyed sockeye eggs in the Nanaimo River in 1933, or resulted from kokanee which may have migrated to sea as juveniles. Kokanee are present in the Nanaimo Lakes and are known to have been present there prior to the introduction of sockeye eggs to the system in 1933.

The construction of the 100 foot high concrete dam on the South Nanaimo River for the Nanaimo water supply in 1931 effectively stopped all salmon migration and in addition, as there was no provision for water release below the dam and no possibility for natural gravel replenishments, made the remainder of the South Nanaimo unsuitable for spawning activity.

There has been a considerable amount of concern over the years over the low summer and fall flows in the river. The most critical area seems to be the 6 or 7 mile section below the M & B pumphouse. When negotiations were underway with M & B on the amount of residual flow to be left below their intake, it was recognized that the 39 cfs. finally obtained was much less than desirable. It was in fact, up until then, the lowest daily flow on record.

In negotiations dating back to 1949 between the Department of Fisheries and M & B, considerable discussion took place regarding the amount of residual flow that should or could be left below their intakes. Although the Department had asked for a minimum of 40 cfs. in dry years considering the amount of storage to be provided, the Company were willing to guarantee only 30 cfs. On June 25, 1949, Mr. R. C. Farrow, Comptroller of Water Rights, advised that as the minimum flow on record was 39.6 cfs. and as there could possibly be drier years in the future, the Department's basis for minimum fisheries flow was invalid. It does not appear that any restriction was placed on the licence at that time but M & B subsequently worked to a value of 30 cfs.

In 1962, when M & B applied for a licence for an additional 25 cfs. our District Supervisor of Fisheries, Mr. G. E. Moore, made comment in one of his letters that at a measured flow of 115 cfs., salmon were having difficulty ascending the river. He said that there was only two inches of water over some of the riffles and was emphatic that the minimum flow of 30 cfs. was not adequate for spawning requirements. He added, however, that the Harmac management had up until then been very cooperative in releasing extra flows over the minimum.

At this time, the Department of Fisheries had conducted some studies indicating that a minimum flow of 75 cfs., based on the minimum mean monthly flow for the years 1914 to 1926, would be most desirable. It was also recognized that in most years M & B would be able to release considerably more than 30 cfs.

In a meeting on May 1, 1962, these views were discussed with M & B but they were not willing to commit themselves firmly to minimum flows in excess of more than 30 cfs. although they admitted that 75 cfs. would be available in most years. The Department then prepared a rule curve for M & B's Fourth Lake reservoir, based on 125 cfs. plant flow, 20 cfs. losses, and 39 cfs. residual, and submitted it to the company on May 18, 1962. Operation of the reservoir to this rule curve would have provided 75 cfs. when the storage was above the rule curve and 39 cfs. when the storage was below the rule curve.

Another meeting was held with M & B on August 8, 1962. They again were not willing to commit themselves to more than

30 cfs. They argued that there could be drier years in the future than those now on record and also claimed that the 48 hour delay of water travel down the river would upset the rule curve.

On December 6, 1962, M & B wrote to Mr. A. F. Paget, Comptroller of Water Rights, agreeing to provide 39 cfs. and to release "...more than this at times when, in our judgment, such water can be made available without jeopardizing the production of the pulp mill."

Further negotiations were continued with M & B during 1963, mainly with regard to a modified rule curve. A revised rule curve dated September 27, 1963, was discussed with M & B on November 14, 1963, and they agreed to use it as a guide only. On February 4, 1964, the rule curve was modified again, in effect guaranteeing a larger reserve in the Fourth Lake reservoir. No further meetings on this subject appear to have taken place. The September 27, 1963, and February 4, 1964, rule curves are included as Figures 8 and 9.

During a survey on November 1, 1972, it was observed that there was inadequate flow in some of the side channels despite the fact that the total measured flow at that date was 46.0 cfs. This flow represented the sum of the residual flow past the M & B intakes and the discharge from Haslam Creek, 9.6 cfs., measured on the same date.

Biologists from the Fish and Wildlife Branch and from the Pacific Biological Station examined the river in August 1972 to determine the cause of an extensive juvenile fish kill which had been reported. In one 1,000 sq. ft. section of the river they counted 250 dead coho plus some dead steelhead and chinook and one adult sockeye. An approximate five mile length of the river was affected in this way. As the temperature of the water was measured at 21° to 25° C. (70°-77° F.), it was concluded that this was the probable cause of the kill. Temperatures over 68° F. are considered to be in the lethal range. The length of time that the water stays at elevated temperatures is a factor. At the time of the kill, there was continuing high air temperatures with little night cooling.

The lower part of the river has a shallow gradient which, when combined with low flows, produces short riffle sections with long shallow pools that are very susceptible to solar heating. First Lake is a shallow lake which heats up considerably during a hot summer. Average water temperatures are agravated by these conditions but can be alleviated by increased minimum flows and introduction of cooler water which would be available from the South Fork reservoirs. Increased flows following summer rains also provide a cooling effect and help to flush the gravel clean as is necessary from time to time in spawning areas.

Upstream migration of the fall runs of coho and chinook are affected by the dry weather flows in September and sometimes in October, (Figure 2). Migration below the M & B intakes will be difficult if the residual flow is too low and migration through the falls area above the intakes will be difficult if the flow in the river is low naturally or low because of lack of adequate releases from the Fourth Lake or South Nanaimo reservoirs.

The problems of inadequate flow provisions for fisheries requirements is not peculiar to the Nanaimo River system, but is of general application in several areas of British Columbia, particularly in the adjacent streams on the East Coast of Vancouver Island. The following section discusses the concept of minimum flows in general, considering the concerns of other potential users.

Review of Current Literature on Minimum Flow Requirements

There is a growing amount of literature on the subject of minimum flows reflecting the increasing concern in many countries and the need for adoption of policies in water management which will incorporate minimum flow concepts.

In 1970, Mr. J. C. Fraser prepared a 166 page bibliography on acceptable flows for fish life in controlled streams for FAO. In his introduction, he says that:

> The development of a river frequently involves the abstraction of water from all or a portion of the river's course resulting in a depleted flow or at times a completely dewatered channel. To serve the purposes of irrigation, hydro-electric power, industrial and domestic uses, a water project planning engineer usually desires to provide the project sponsor with the most water for the least unit cost. Frequently this means a drastic reduction in downstream flow releases which is especially critical in the normally low-flow months and in dry years.
>
> Inadequate stream flows below reservoirs have resulted in depletion or elimination of fish populations, increased pollution problems, destruction of forests, disruption of navigation, elimination of downstream water supplies, alteration of the ecology of estuaries, creation of health problems, destruction of aesthetics and the upsetting of local social structures and economies.

> Most often the adverse effects were not anticipated and could have been prevented by adequate advance study and planning. In still other cases, the problems were pointed out but in the absence of studies leading to well justified conclusions and solutions, the project developers have forged ahead with the project construction and without adequate releases of water to the river.
>
> Biologists the world over have decried the lack of consideration of downstream ecology and the environment in water project planning. The harassed water engineer is now asking for answers from the biologist. How much flow of water is needed in downstream areas to maintain fish populations, the aesthetics, the recreation values, suitable water quality, etc. ...
>
> ...Biologists are beginning to quantify the basic water needs of the many species of fish and although progress in this direction is frustratingly slow, herein lies the logical and appropriate method and the ultimate answer to the question of deciding the quantitative water needs of a stream's biota.

In his paper, "Regulated Discharge and the Stream Environment," Mr. Fraser comments on existing water laws:

> Few areas of the world have laws which give any status or protection to water supplies for the purpose of maintaining a stream, its ecology, or its other inplace values. Water laws throughout the world, and especially in the United States, were formulated to stimulate development of the land and frequently encourage the diversion of water away from the stream.
>
> Provision for in-stream water rights or protection of a basic discharge, except possibly for purposes of navigation, are nonexistent in most water laws. Many states in the United States have no legal machinery for maintaining discharge in a stream to protect the stream's ecology or other in-place public values. The well established doctrine of diversion as the basis for water rights and the use of water remains as an invidious force in the water laws of most states. It will continue to prevent appropriate consideration and protection of stream flows until rescinded by new legislation which clearly gives weight and protection to water for in-place stream values.
>
> One of the tragedies of our times is the legacy of private ownership of rivers or of water diverted from them in the United States. True, such ownership

stimulated and facilitated settling of the land in the pioneering frontier days, but it now forms an effective block to environmental management of water resources in the public interest. The use and values of a river are no longer tied solely to the individual landowner or holder of a water right -- they frequently extend more importantly to the public as a whole.

A number of state laws in the U.S. provide language to effect some consideration of 'minimum' flows for protection of fish life, but all too frequently these have been interpreted so conservatively as to constitute a legislative state-wide impairment of the ecology and aesthetics of rivers. The legal situation in some states is so weak or so protective of water for diversion that despite the availability of water and money to correct or prevent an ecological mistake, it cannot be accomplished.

Fortunately, the rivers and streams of Australia have been retained in public ownership. The environmental water needs of Australia will certainly be more easily considered as a result of this farsighted action. The wild rivers legislation in the United States is a majorstep in the direction of protecting some river values, but much more needs to be done.

There is need for a worldwide review and revision of water laws if the ecological and environmental values of streams are to receive effective attention. Where no legal foundation has yet been developed to recognize and protect the interests of the general public in the ecology and in-place uses of streams, the legislatures should be asked to take corrective action. The ability to preserve adequate stream flows in relation to future developments should be given statutory implementation wherever it does not presently exist. It may well be necessary to provide the power and the funds to condemn and purchase water rights, including riparian rights, to prevent or to correct serious ecological mistakes caused by inappropriately regulated river discharges.

In the same paper, he says that:

It should also be recognized that the life habits of salmon and trout are geared to centuries of evolutionary adjustments to the seasonal variations of their flowing water environment.

He covers in some detail the requirements for the several phases of the life cycle of salmon and trout as indicated by the following excerpts:

Migration. Migrations of fish are affected by the amount of discharge in a number of ways. Discharge can cause migrations to commence, create barriers at high or low flows, cause delays, disrupt normal routing, and change the speed of travel. The role of discharge in inducing migrations of fish is important in many species and may vary between species and between streams for the same species. Most, but not all, salmon migrations occur at times of the year when increasing or seasonally high discharge can be expected. In some rivers, such as the Sacramento River in California, there are peaks of migrations, but some salmon enter the river in almost every month of the year.

... Reduced flows can cause undesirable delays in migration. Brett (1957) noted that delays in the upstream migration of adult salmonids cause premature use of energy reserves and develop stresses causing death or reduced reproductive success. The low tolerance of salmon to delays was also noted by Hourston (1958) ...

... Points of difficult passage or complete barriers to migration can develop with reduced discharge, despite the appearance of adequate flows for passage in most of the stream (Andrew and Green, 1960; Hourston, 1958; Deschamps, Wright, and Magee, 1966). ...

... Downstream migrant salmonids usually have a strong orientation to current. The dependence on this orientation varies with the species, and among the salmon it is particularly pronounced. Mackinnon and Hoar (1953) demonstrated that chum and coho salmon smolts responded positively to changes in water flow. Both species were found to respond to the stronger of two parallel laminar currents, but the chum salmon were better able to distinguish very small differences in flow.

The rate of downstream migration of juvenile fish can be greatly influenced by the discharge and its velocity. The migration rate of young chinook salmon (O. Tshawytscha) in the Snake and Columbia rivers was found by Raymond (1968) to be in general directly related to stream flow. Low river flows increased the travel time and contributed to delays in the migration of young salmon to the ocean. ...

... The role of discharge is thus extremely important to anadromous species. The stimulus and orientation provided by a current appears essential to the migration of many species. A current-oriented downstream migrant is placed in a time-delay and stress situation in the absence or curtailment of current and certainly cannot be expected to adjust to a flow reversal situation as described by Ganssie and Kelley (1963). ...

... Spawning. Virtually all stream-dwelling fishes have adapted their spawning activities to some range of water velocity and depth. Knowledge of this range is one of the key factors in the management of salmon and steelhead populations and is probably a key factor in the ecology of most, if not all, streams. Considerable attention has been given by many investigators to discharge in relation to those species which commonly spawn in rapidly flowing water, but discharge can be equally important to many species which spawn in slow-moving sections or in the still waters of seasonally flooded areas.

Velocity of stream flow is a factor in salmon and trout redd construction, in the fertilization of the eggs, and in supplying oxygen to the eggs. Subsurface flow is essential in maintaining high oxygen levels for salmon (Alderdice, Wickett, and Brett, 1958; Wickett, 1954 and 1958). Generally, salmon appear to select gravels with an adequate oxygen supply by sensing a current or upwelling of flow through the gravels. Andrew and Green (1960) suggest such a selection process. Surface flow plays a major role in the subsurface flows which keep the eggs oxygenated.

Work has been done by a number of fisheries' biologists to quantify the water velocity and depth preferences of spawning salmon and trout. These studies have demonstrated that salmon and steelhead have a rather narrow tolerance to velocity and depth when choosing spawning areas. These velocities and depths have been measured on many rivers and although there are some variations between rivers, the velocity and depth tolerances for salmon and steelhead in west coast American rivers have been fairly well determined. It has been a major step in quantifying the elements of a stream's ecology. ...

... Rearing Capacity (including embryo development and food production.)

Surface flow influences subsurface flow and is therefore important to the survival of salmon and steelhead eggs. However, excessive or widely fluctuating flows can be detrimental to salmonid egg survival. Lister and Walker (1966) found that winter discharge stability increased the egg-to-fry survival of chum salmon and that the magnitude of coho salmon fry emigration was also related to winter discharge stability. This study further demonstrated the very strong relationship between discharge and reproductive success in salmon. ...

... Egg survival and the success of the juvenile fish after hatching determine the rearing capacity of the stream, and food and shelter are essential elements for this survival and growth. Discharge influences

> the fish-food species composition (Phillipson, 1954) and total production, as well as the availability of shelter. In salmon and trout streams the production of fish-food organisms is highest in the riffle or rapid-flow areas, and the turbulent and "white-water" areas provide a significant part of the shelter needed by the young fish. ...
>
> ... Turning to the rearing capacity of streams, some recent studies on juvenile salmon production are very interesting. Two recent unpublished papers point up the significance of discharge and velocity to the rearing capacity of a stream. Erho et al. (unpublished) found that coho salmon smolt production was in direct proportion to the July, August, and September discharge in Speelyai Creek in Washington. The data support the thesis advanced by Smoker (1953) that stream flow is a limiting factor in the production of coho salmon.
>
> The studies of Pearson, Conover, and Sams (unpublished) further support the contention that the most important factor determining the juvenile coho carrying capacity of a stream is the summer discharge. They studied the summer rearing requirements of juvenile coho salmon and the effects of diminished flows in nineteen streams in four river systems in Oregon. They concluded that production of juvenile coho was directly related to summer stream flows and that increases in populations associated with increased flows were also velocity-related. Their studies indicate clearly that reduction of summer flows would result in a reduced production of coho salmon. They found that each stream and each pool in a stream has a definite rearing capacity which is influenced by food production and spatial requirements of the fish in turn affected greatly by velocity of the stream flow.

In England the Water Resources Act of 1963 contained a provision for determination of minimum acceptable flows. It placed the responsibility upon River Authorities in consultation with the Water Resources Board to set:

> a. The control points at which the flow of water is to be measured, and the method of measurement to be used at each control point;
> b. The flow which is to be the minimum acceptable flow at each control point.

Section 19(5) of the Act states in part:

> (The minimum acceptable flow shall be that) which in the opinion of the river authority is needed for safeguarding the public heath and for meeting (in respect both of quantity and quality of water) the requirements of existing lawful uses... and the requirements of land drainage, navigation, and fisheries, both in relation to that inland water and in relation to other inland water, whose flow may be affected. ...

In 1955 the Oregon Legislature enacted a water code which provided for:

> The maintenance of minimum perennial stream flows sufficient to support aquatic life...

For several rivers, after submission of study reports, minimum flows were set:

> ...based on fish life need, and consequently, varied by season throughout the year. ...the stream and all its tributaries above the control point were protected to the degree required to provide the minimum at that point, and that volume was to continue downstream to the mouth of the river or to the next lower control point.

As part of a State Water Plan the Idaho Fish and Game Department, under contract with the Water Resource Board, prepared a report in 1969 entitled, "Aquatic Life Water Needs". The introduction states in part that:

> ... The use of water, to maintain or enhance fish and wildlife habitat and populations, has in recent years become a generally accepted concept among water resource planning agencies. Legislation creating the Idaho Water Resource Board directed along with other requirements that fish and wildlife needs be considered in State water planning. In order to meet this charge, and in the interests of comprehensive water planning, the Water Resource Board early recognized the need for basic knowledge of the State's fish and wildlife water requirements by asking for a study of the aquatic life water needs.

Their report established on a preliminary basis sustained minimum flows for main streams based on biological considerations of water quality, food, escape cover, reproduction and fish passage.

Recommendations

It is recommended that the watershed area and storage sites available upstream of the 1931 dam be developed in the most beneficial way possible for future Regional needs, recognizing the increasing demand by the expanding population on the east coast of Vancouver Island and the consequent encroachment on the natural fish habitat.

Study of Nanaimo River flow records from 1914 to 1927, before construction of the 1931 dam on the South Nanaimo River, (Appendix A), shows that a minimum flow of 50 cusecs could have been maintained with very little storage. The contribution of the watershed above the dam is approximately 35% of the total Nanaimo River flow so that its contribution to the minimum flow should be 35% of 50 or 17.5 cfs. Any flow increase below the 1931 dam should of course be reflected downstream below the M & B intakes where the most critical area exists. Because of the desirability for the river habitat to receive the beneficial effects of summer and fall rains natural flow increases should be released rather than allowing the reservoir to be replenished. It was observed that at the end of the dry season last year (October 31, 1972) the reservoir behind the 1931 dam was completely full because of retention of summer flows. Judicious releases of this water which was not being used could have prevented the fish kill described above.

It is believed that every attempt should be made to preserve the river habitat and, where there has been previous degradation, to restore it whenever possible. Natural flows in the river below the 1931 dam can be readily reinstated when new facilities are built, and adequate facilities should be incorporated during the engineering design stages. The development of storage facilities above the existing dam is not likely to cause particular concern to fisheries except during land clearing and construction phases when silt and debris could be washed down unless suitable precautions are taken.

The requirement of release of water for fisheries' use, which should be from a deep, cool water source, is covered by section 20(10) of the Fisheries Act which states:

> The owner or occupier of any slide, dam or other obstruction shall permit to escape into the river bed below the said slide, dam or other obstruction, such quantity of water, at all times, as will, in the opinion of the Minister, be sufficient for the safety of fish and for the flooding of the spawning ground to such depth as will, in the opinion of the Minister, be necessary for the safety of the ova deposited thereon. R.S., c. 119, s. 20.

In order to manage releases for fisheries flow several gauges on the river and some form of continuous monitoring and control of reservoir level will be needed. The following proposed requirements are based on the above considerations:

1. The minimum instantaneous flow shall be 17.5 cfs. below the 1931 dam on the South Fork of the Nanaimo River and also shall be 50 cfs. downstream of the MacMillan and Bloedel intakes in the main stem of the Nanaimo River above the confluence with Haslam Creek except as provided in Clause 4.
2. All reservoirs on the Nanaimo River system including Fourth Lake, Jump Creek, and South Fork (1931 dam) shall be operated under the provisions of rule curves such that the minimum flows noted above are quaranteed and when natural flows are available the minimum flow will be increased to 75 cfs. or greater during spawning periods below the M & B intakes. These rule curves will be subject to the approval of the Comptroller of Water Rights and the Canada Department of the Environment, Fisheries and Marine Service and the B.C. Fish and Wildlife Branch.

3. In order to provide additional flows, facilities must be installed below the 1931 dam for releasing up to at least 40 cfs., at minimum reservoir level, into the river and for metering the discharge into the river.
4. If, in the judgment of the Canada Fisheries Service and the B.C. Fish and Wildlife Branch, it is felt that the minimum flow may be reduced, then the equivalent amount of water must be held in storage and released without diversion at a later date as ordered jointly by the fisheries agencies. (This provision may be necessary in abnormally dry years if it is felt that insufficient flow would be available for spawning in the fall months.)
5. The following additional continuous recording gauges will be provided and subsequently maintained by the Water Survey of Canada: at the expense of the Greater Nanaimo Water District - below the 1931 dam on the South Fork; and, at the expense of MacMillan-Bloedel Ltd. - below the company intakes on the Nanaimo River above the confluence with Haslam Creek.
6. Additional provisions or precautions or changes may be necessary to protect the fisheries' resource after a trial operating period and Fisheries Service reserves the right to take whatever action is deemed necessary as provided under the Fisheries Act.

It is to be noted that protection of the Nanaimo River salmon runs is not inconsistent with development of water use. It is management and control of flows which is important. Dry weather flows in the main Nanaimo River above the M & B intakes are in reality much higher due to releases from Fourth Lake and this is somewhat advantageous. The main fisheries low water problems occur below the intakes and conditions there can be alleviated by providing flow releases from the Nanaimo River reservoirs as detailed above and also controlling surges during critical migration times.

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Literature and Reports Cited

ANON. 1969. Aquatic life water needs. Planning Report #3. The Idaho Fish & Game Department. Boise, Idaho.

ARO, K.V. MS, 1972. Salmon and migratory trout of the Nanaimo River and adjacent streams. Pacific Biological Station, Nanaimo, B.C. (1178).

ASSOCIATED ENGINEERING SERVICES LTD. January 5, 1970. Report on water supply for Greater Nanaimo Water District.

ASSOCIATED ENGINEERING SERVICES LTD. July 24, 1972. Report on regional water study for Regional District.

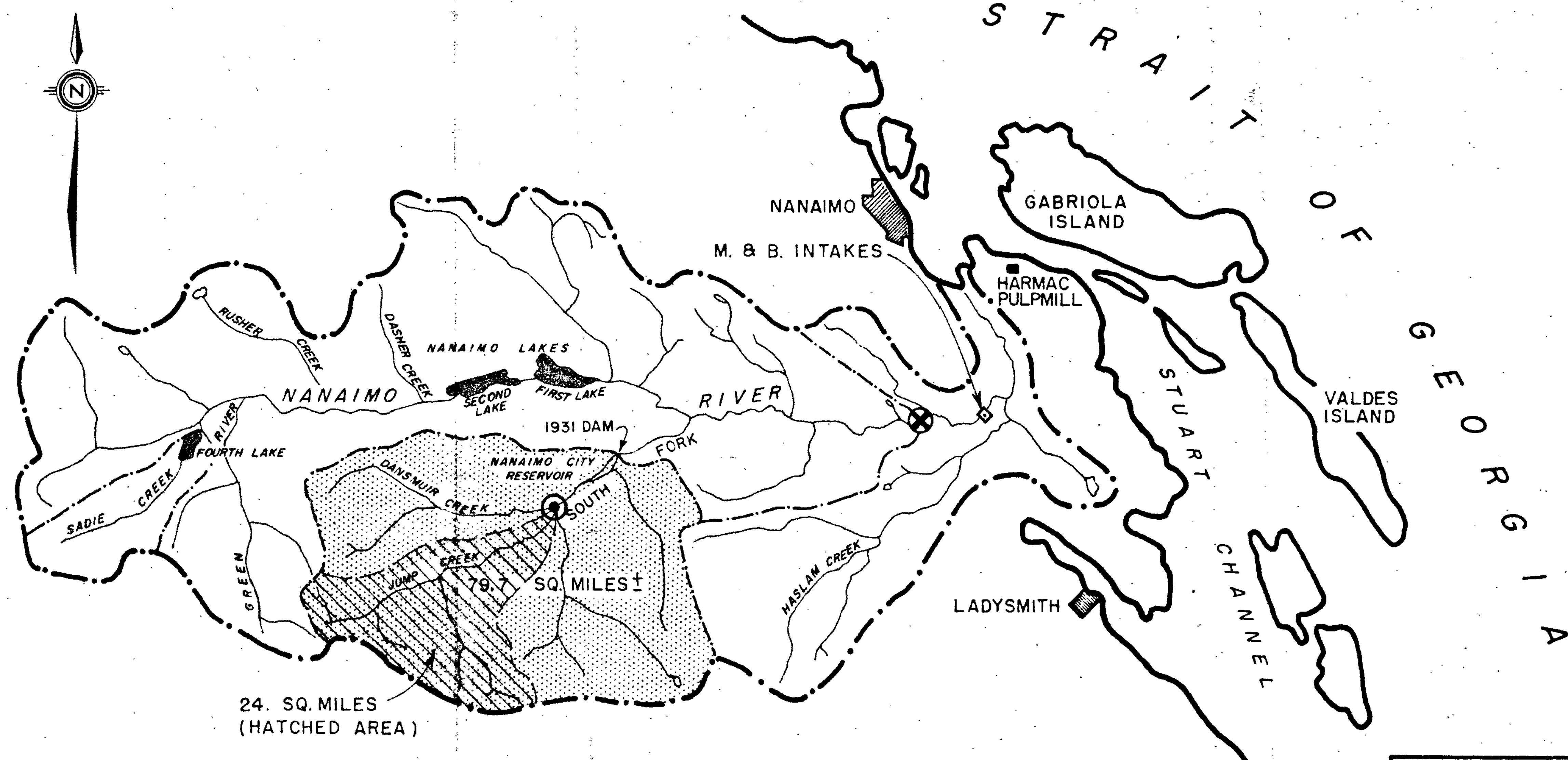
BOULTON, A. GERARD. 1965. Minimum acceptable flow. Institution of Water Engineers. 19(1) : 15.

FRASER, J.C. Regulated discharge and the stream environment.

FRASER, J.C. 1970. An annotated bibliography on the establishment of acceptable flows in controlled streams. FAO. EIFAC 70/SC. Rome : 111-4.

PITNEY, WILLIAM E. Determination of stream flows for fish life. Oregon State Game Commission.

FIG. 1



LEGEND

—·—·— OUTLINE OF DRAINAGE AREAS

⊗ GAUGING STATION AT EXTENSION ON THE NANAIMO RIVER (249 SQ. MI. DRAINAGE AREA) 08HB034

⊙ GAUGING STATION AT JUMP CREEK 08HB041 (24 SQ. MI. DRAINAGE AREA)

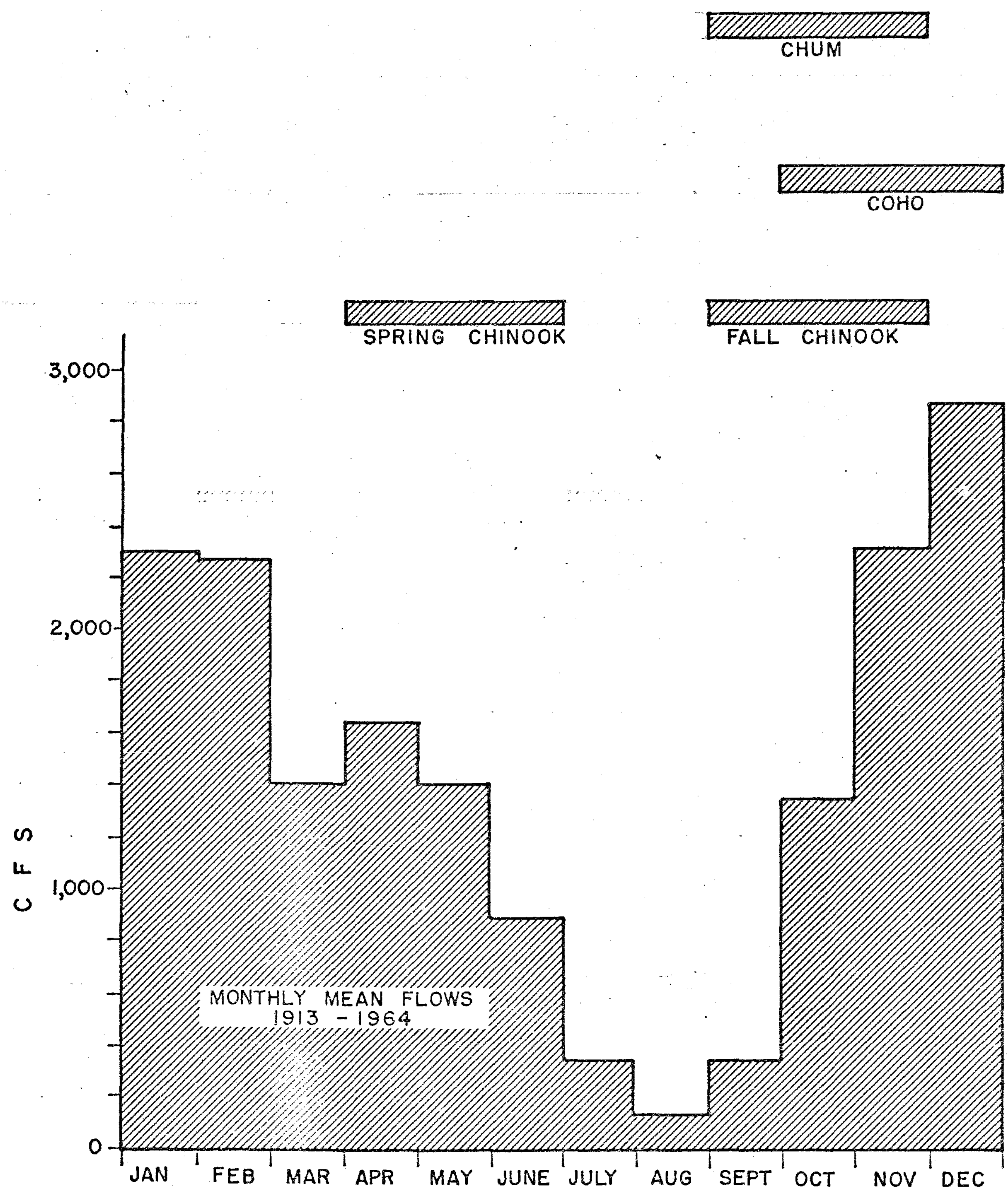
SCALE 4 0 4 MILES

DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

NANAIMO RIVER
DRAINAGE AREA

DRAWN: A. C.	DATE: APR. 1973
CHECK: R.H.	SCALE: AS SHOWN
APPROVE: A.F.L.	DRAWING NO.

FIG. 2



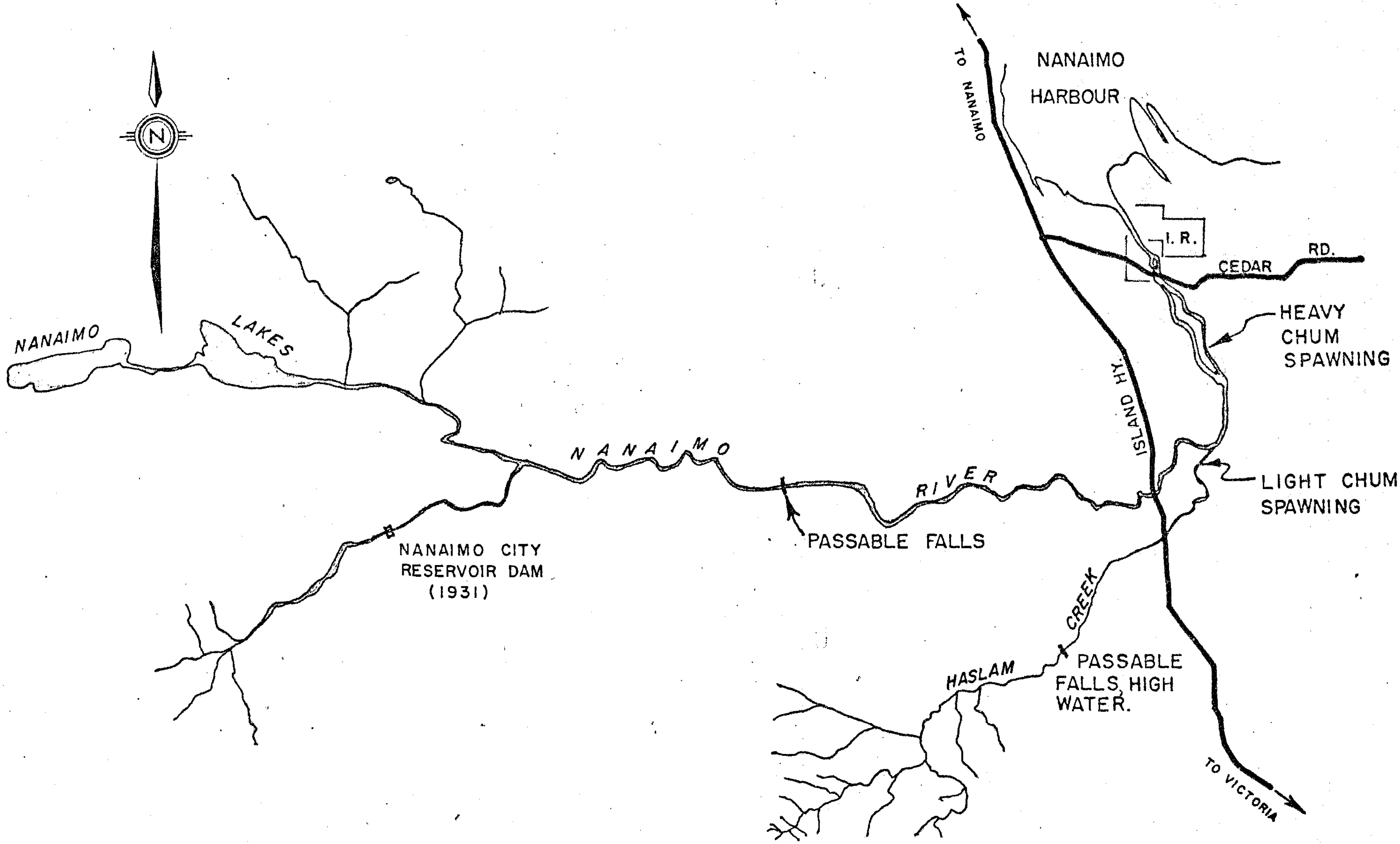
NANAIMO RIVER MEAN MONTHLY FLOW & SPAWNING PERIODS

MAIN WATER LICENCES ON NANAIMO RIVER

Date	Licence Cond.	Licence Final	Licensee	Quantity	Purpose	Remarks
May 8, 1908	Amend 7001		City of Nanaimo	4,500,000 G.A.D. (8.4 c.f.s.)	WWKS	
Feb. 2, 1948	Amend 19308	19385	M & B	40 c.f.s.	Industrial	
Jan. 26,1951	20011		M & B	35,000 AC Ft.	Storage	4th Lake Reservoir
May 31, 1951	20247	19387	M & B	60 c.f.s.	Industrial	
May 21, 1954	Amend 22272		Greater Nanaimo Water District	9,500,000 G.A.D. (17.6 c.f.s.)	WWKS	
May 21, 1954	Amend 22273		Greater Nanaimo Water District	2,460 AC Ft.	Storage	Reservoir on S.Nanaimo
Feb. 8, 1955	Amend 22587		Greater Nanaimo Water District	100 AC ft.	Storage	
Mar. 8, 1960	25842		N.Cedar Wwks District	200,000 G.A.D. (0.37 c.f.s.)	WWKS	
Nov.17,1961	27219		Butler Lafarge	1.0 c.f.s.	Industrial	
Jan.10,1962	28119	21212	M & B	25 c.f.s.	Industrial	Maintain 39 c.f.s. in river
Dec.31, 1970			Greater Nanaimo Water District	25 M.G.D. (4.6 c.f.s)	WWKS	
Dec. 31, 1970			Greater Nanaimo Water District	10,000 AC ft.	Storage	Jump Creek Storage
Jan.25,1973			Greater Nanaimo Water District	15 M.G.D. (28 c.f.s.)	WWKS	

MAIN WATER LICENCES ON NANAIMO RIVER

FIG. 3



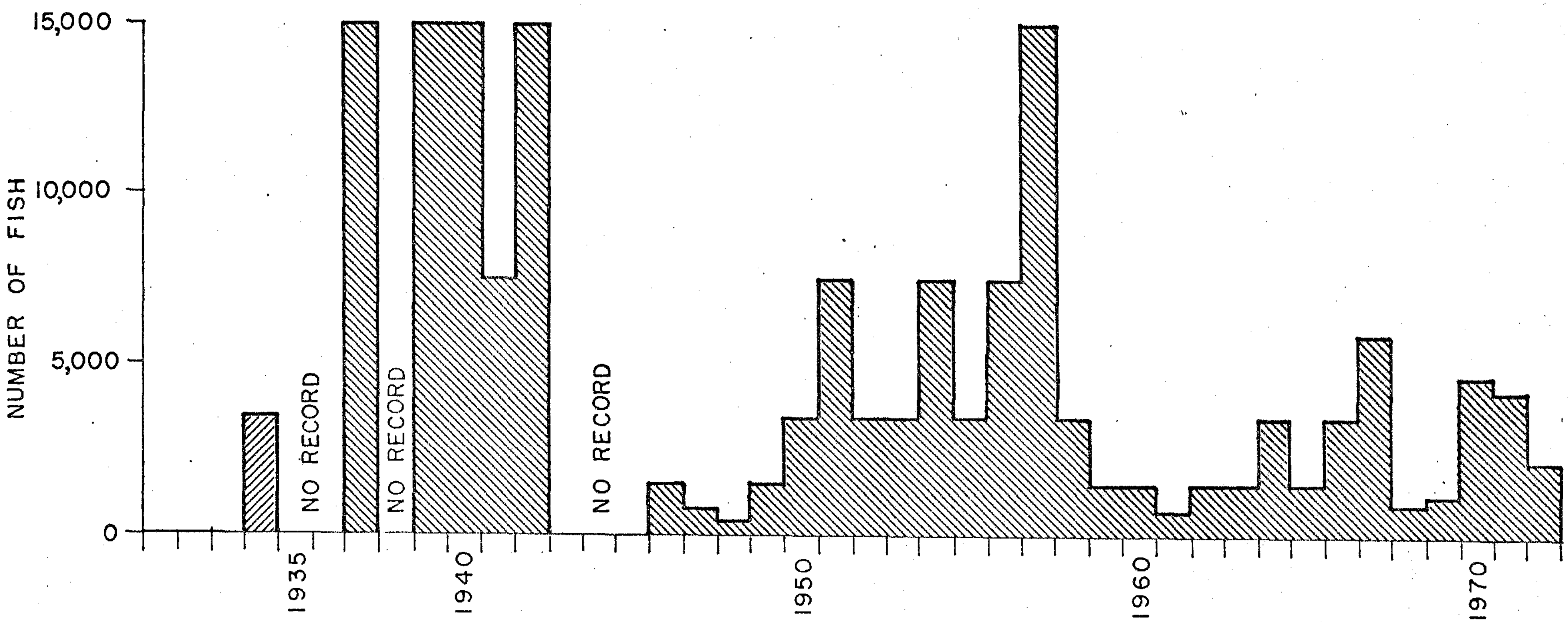
CHUM

COHO

SPRINGS

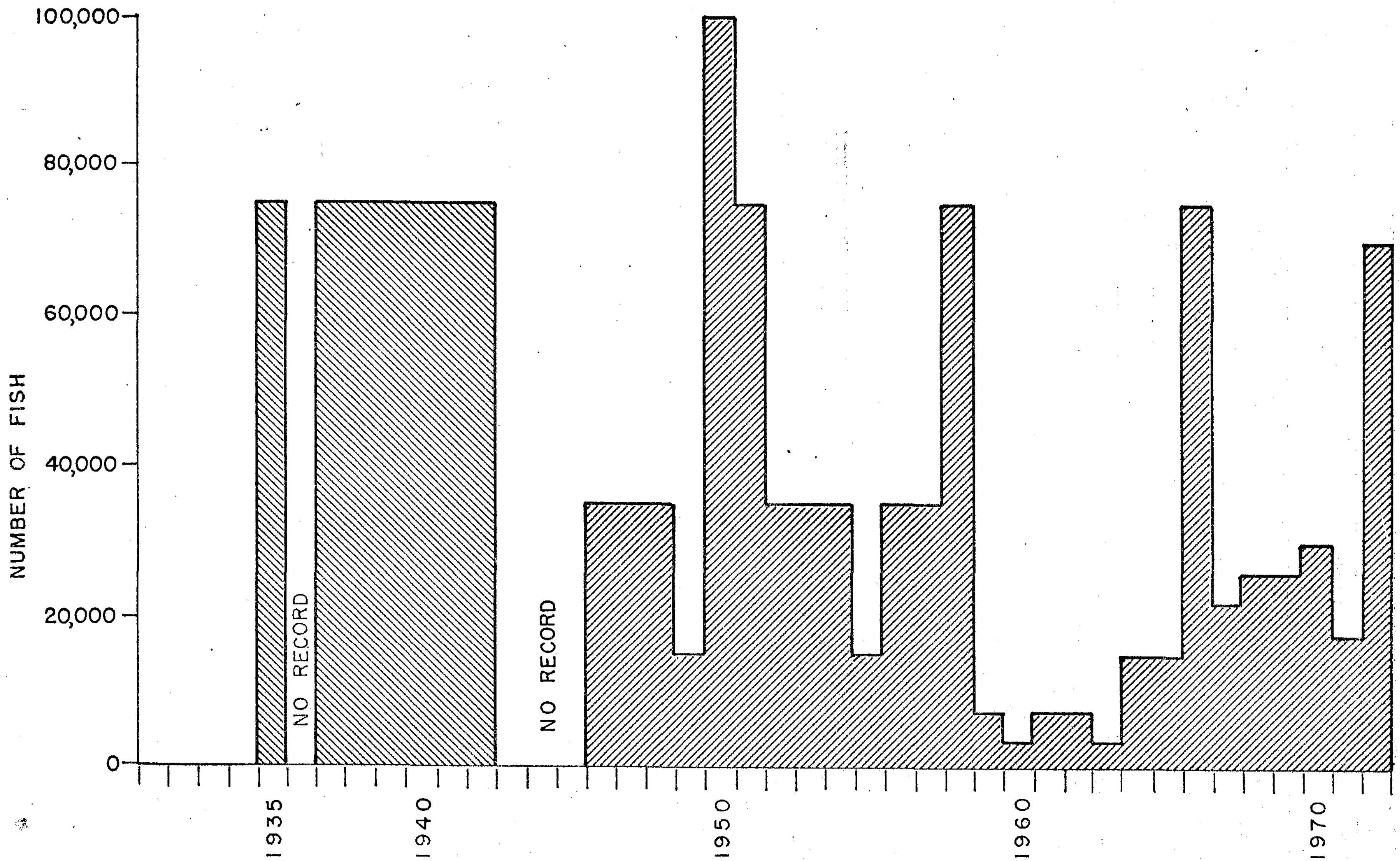
NANAIMO RIVER
SPAWNING DISTRIBUTION

FIG. 4



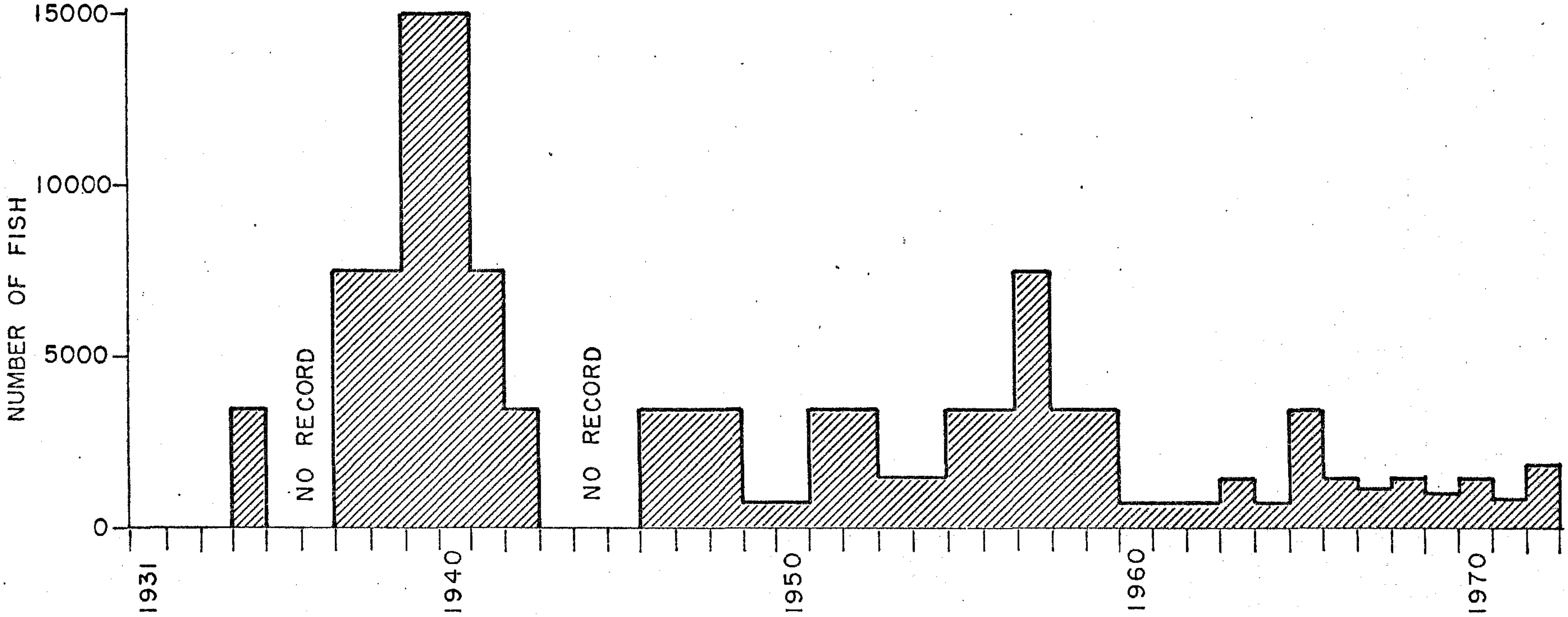
NANAIMO RIVER NUMBER OF COHO SALMON RETURNING TO SPAWN

FIG. 5



NANAIMO RIVER NUMBER OF CHUM SALMON RETURNING TO SPAWN

FIG. 6



NANAIMO RIVER NUMBER OF SPRING SALMON RETURNING TO SPAWN

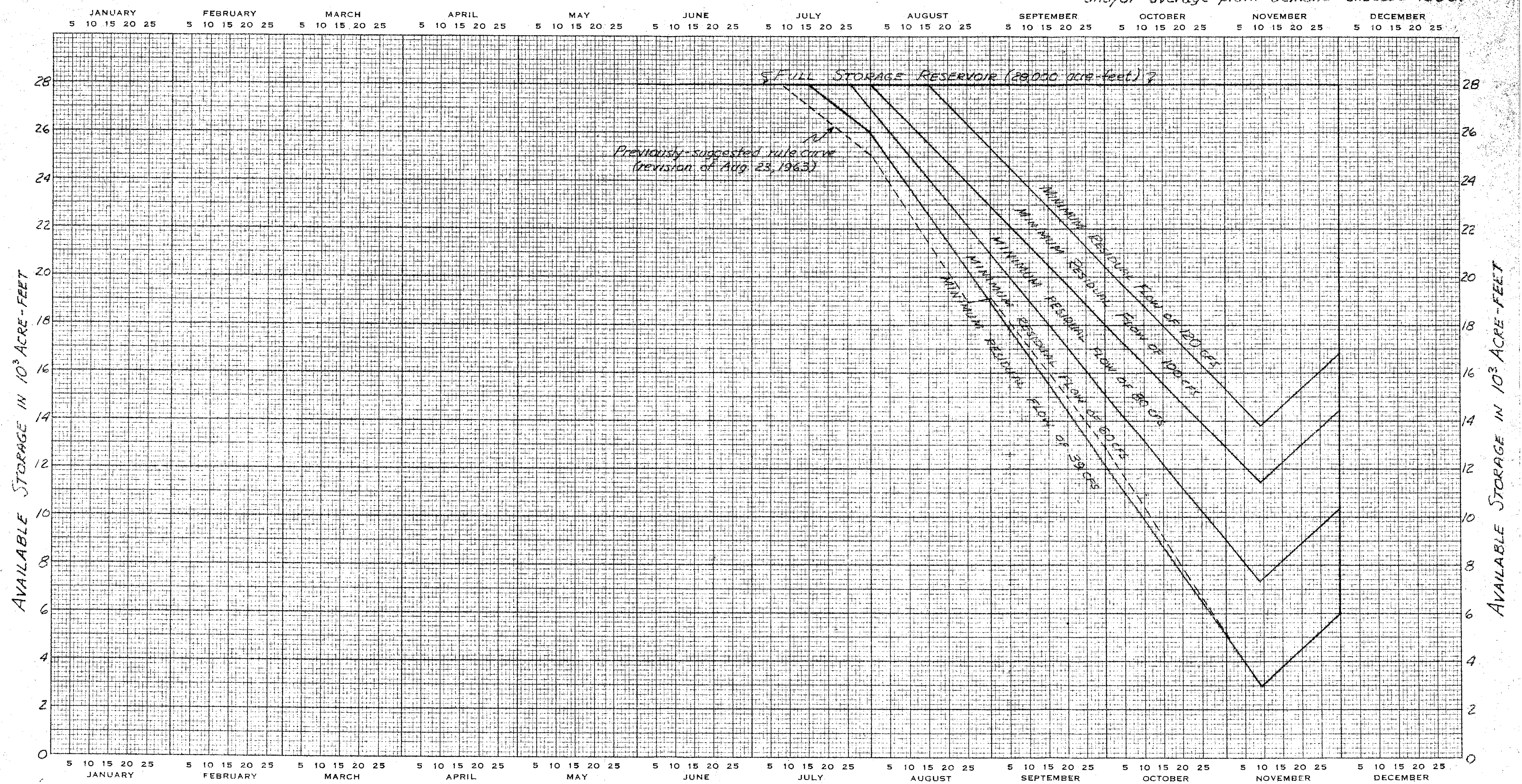
FIG. 7

DEPARTMENT OF FISHERIES OF CANADA FIG 8

NANAIMO RIVER - HARMAC MILL DIVERSION

SUGGESTED INTERIM RULE CURVE*

-To be employed until actual losses are determined and/or average plant demand exceeds 100cfs



*revised Sept. 27, 1963

Low Flow Periods and Required Storage

Figures A1 to A6 are hydrographs for the summer months for the driest years on record. Hydrographs for years subsequent to construction of the Fourth Lake dam in 1954 show much higher flows because the Nanaimo River gauging station reads the natural flow plus the release from Fourth Lake. For the years before 1954, and more certainly before 1931, it is assumed that the gauge indicated only natural flows.

As can be seen from the figures the flow dropped below 50 cfs. for periods up to 2½ months. Study of hydrological records also shows that for 8 years out of 19, flows dropped to below 50 cfs. The folliwng table gives, for each year, the storage that would have been required to maintain a minimum flow of 50 cfs. The last column of the table shows the storage requirements apportioned to the watershed above the 1931 dam on the South Fork. The maximum storage requirement was for the year 1951.

Year	Storage required to have maintained 50 c.f.s.	35% of last column
1914	0 Ac. Ft.	0 Ac. Ft.
1915	0	0
1916	0	0
1917	0	0
1918	102	36
1919	0	0
1920	132	46
1921	0	0
1922	0	0
1923	32	11
1924	220	77
1925	230	81
1926	830	290
1949	0	0
1950	0	0
1951	1000	350
1952	180	63
1953	0	0
1954	0	0

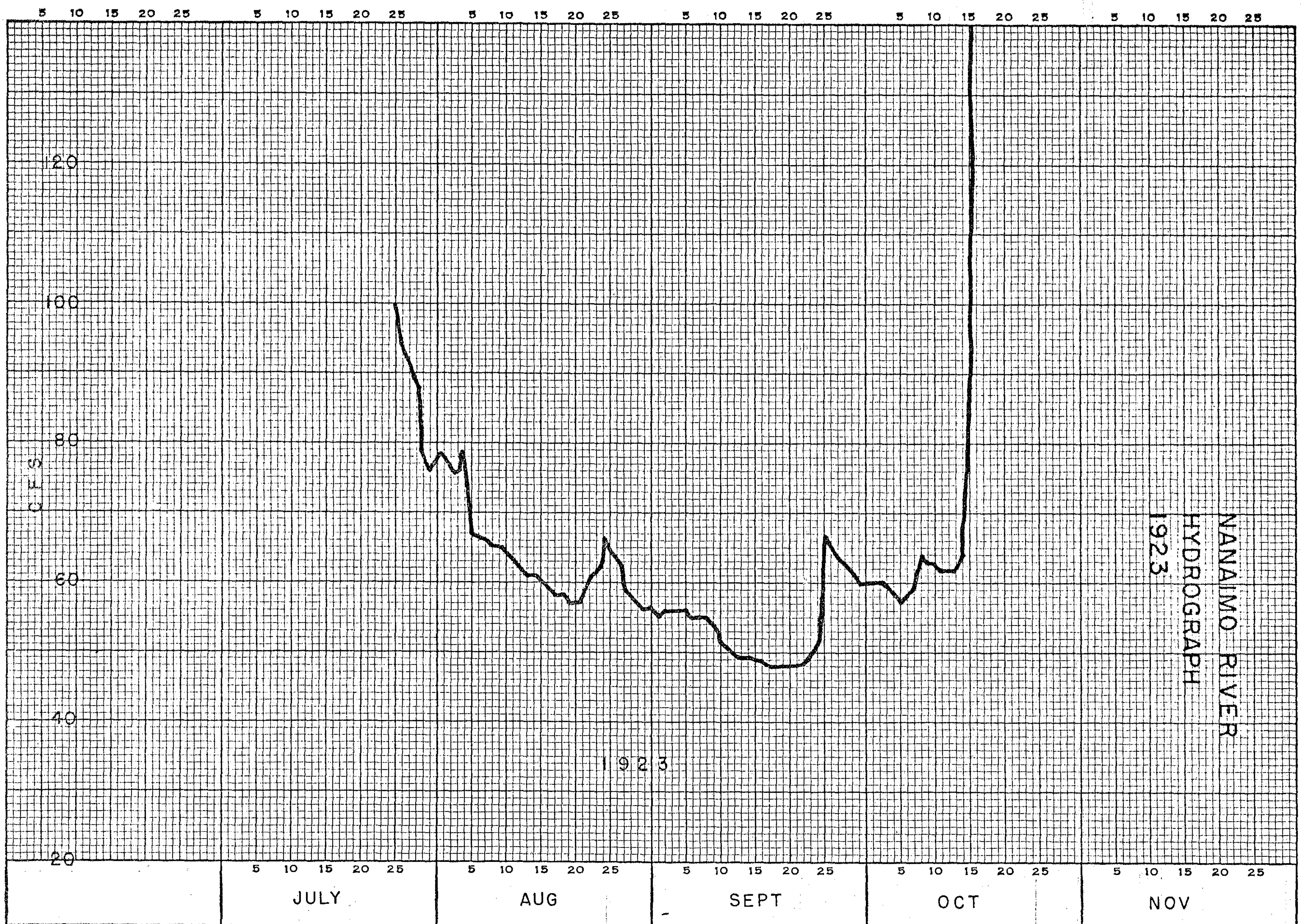

NANAIMO RIVER
HYDROGRAPH
1923
C F S
120
100
80
60
40
20
1923
JULY
AUG
SEPT
OCT
NOV

FIG. AI


NANAIMO RIVER
HYDROGRAPH
1924
C F S
120
100
80
60
40
20
1 9 2 4
5 10 15 20 25
JULY
AUG
SEPT
OCT
NOV

FIG. A2


NANAIMO RIVER
HYDROGRAPH
1925
C F S
120
100
80
60
40
20
1925
5 10 15 20 25
JULY
AUG
SEPT
OCT
NOV

FIG. A3

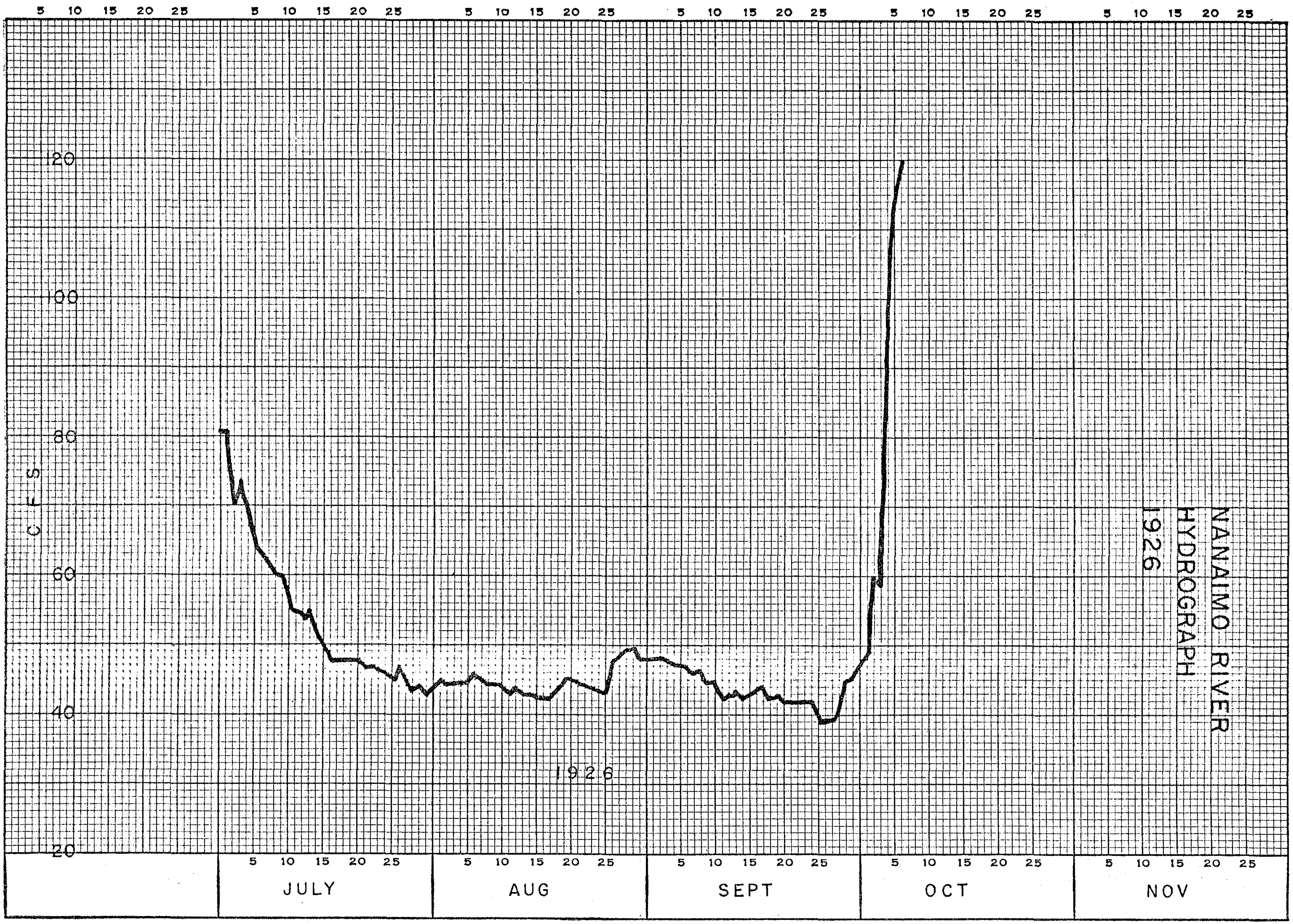

NANAIMO RIVER
HYDROGRAPH
1926
C F S
120
100
80
60
40
20
1926
5 10 15 20 25
JULY
AUG
SEPT
OCT
NOV

FIG. A4

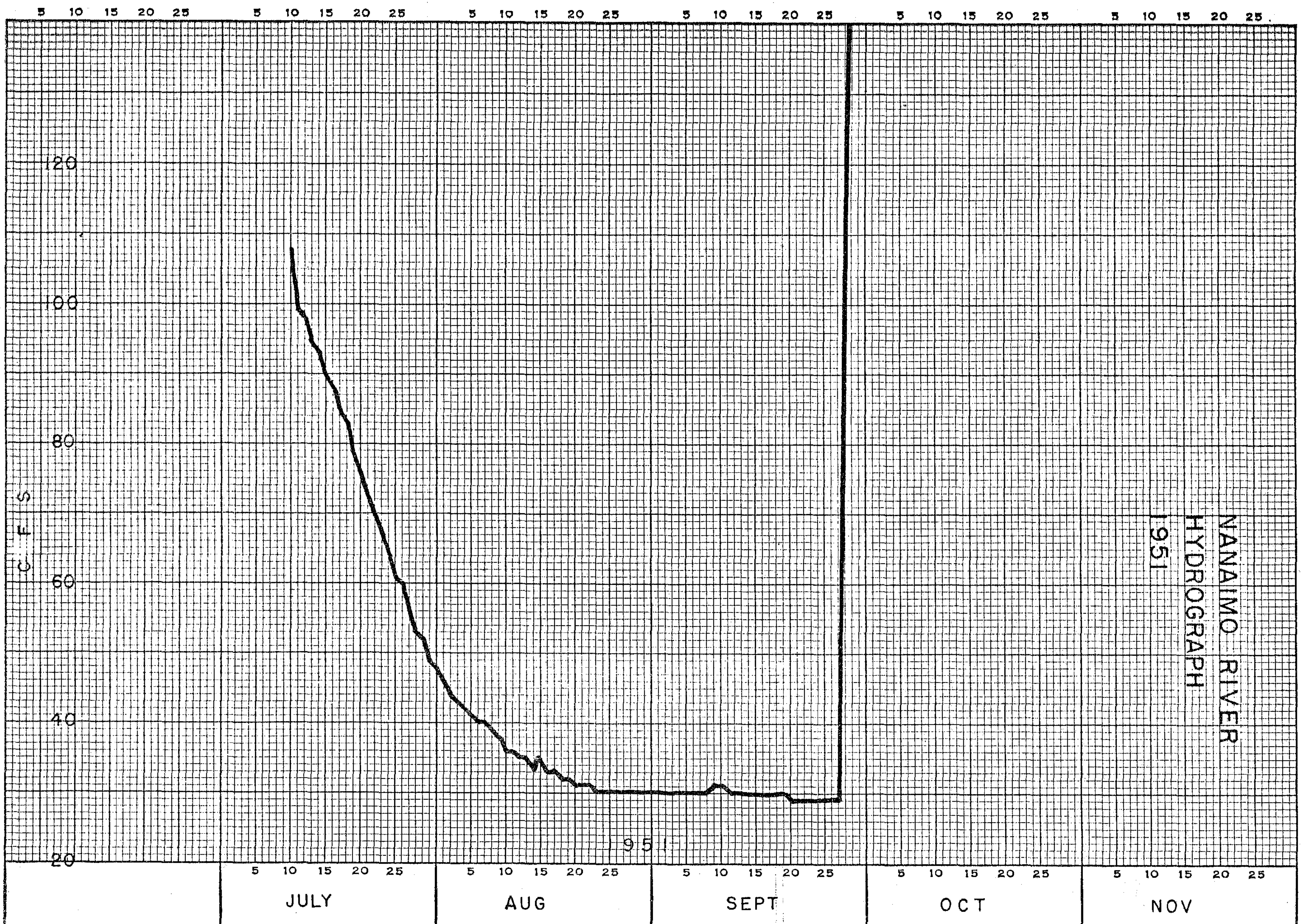

NANAIMO RIVER
HYDROGRAPH
1951
C F S
120
100
80
60
40
20
5 10 15 20 25
JULY
AUG
SEPT
OCT
NOV
951

FIG. A5


NANAIMO RIVER
HYDROGRAPH
1952
C F S
120
100
80
60
40
20
1952
5 10 15 20 25
JULY
AUG
SEPT
OCT
NOV

FIG. A6

FIG. B1

APPENDIX B

FOURTH LAKE DISCHARGE THROUGH TUNNEL

YEARS 1954 - 1962

All quantities in acre feet

		JUNE	JULY	AUG	SEPT	OCT	NOV	TOTAL
1954	A							
	B			976		1386	8880	11,242
1955	A			936	4335	760		6,031
	B							
1956	A			7475	8700			16,175
	B				2064	6764		8,828
1957	A				738	1400		2,138
	B							
1958	A		1878	3515	1512	390		7,295
	B					560		560
1959	A		224	3010	620			3,630
	B					3007	1650	4,657
1960	A		1290	3200	1720	936		7,146
	B							
1961	A							
	B	4335	8260	3995	726			17,316
1962	A		600	560	714			1,874
	B				12,850	2079	1134	16,063

A = Water released to supplement river flow

B = Water released to lower lake level

(From table prepared by M & B at Harmac Jan.1963)

K+E 10 X 10 TO THE INCH 7 X 10 INCHES 46 0705 MADE IN U.S.A. KEUFFEL & ESSER CO.

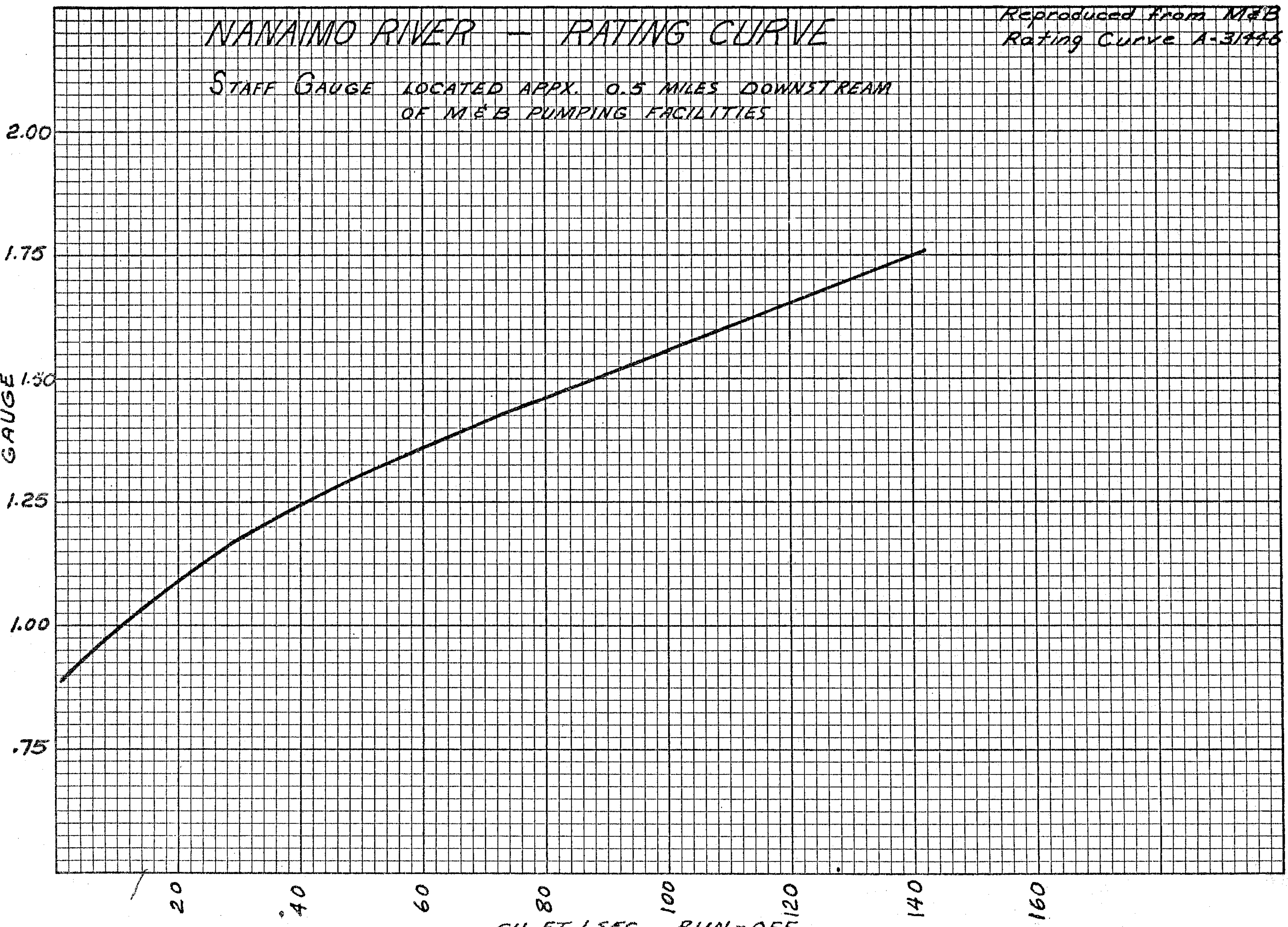


FIG. B2