Effects on Fish and Game Species of Development of Duncan Dam for Hydro-electric Purposes

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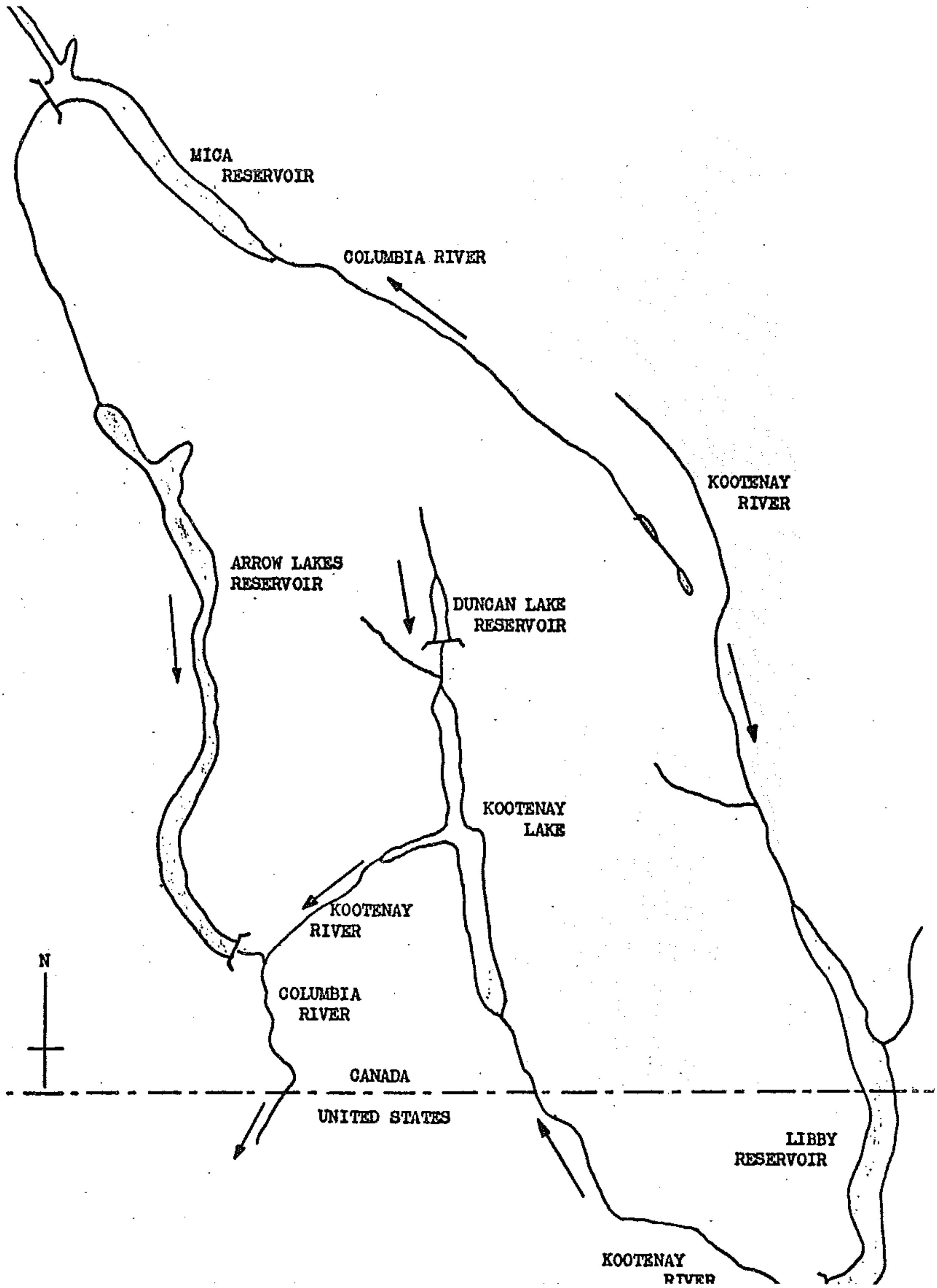


FIGURE 1, Canadian portion of Columbia River Development Plan

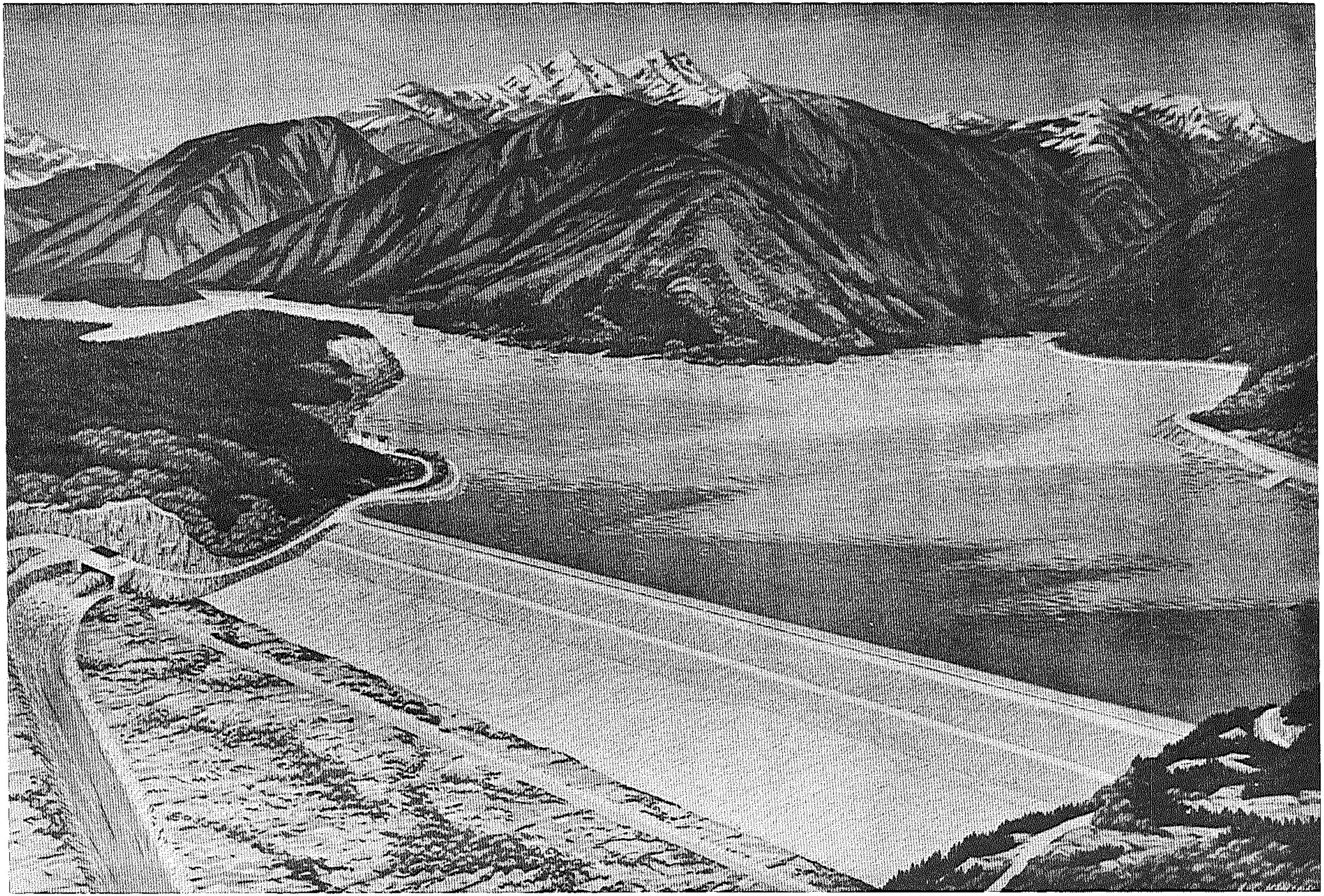


FIGURE 2, **Artist's Conception – Duncan Dam – Columbia River Development Project**

Courtesy - B.C. Hydro and Power Authority

INTRODUCTION

PURPOSE OF SURVEY

This report describes investigations carried out in 1962 and 1963 to assess the probable effects of the proposed Duncan Lake dam on fish and game populations. Where possible, this report contains recommendations for compensation for sport fish and game resource losses attributable to the project.

METHODS OF SURVEY

Fish

The Duncan fisheries survey was divided into two parts; (1) lake survey, and (2) stream and migratory fish survey.

(1) Lake Survey

Surface plankton hauls, vertical temperature readings, Secchi disc readings and gill net sets were made at intervals during the summer (May to September) of 1963.

Bottom fauna samples were collected with a 9 inch Ekman dredge and sorted through a wire-screen bottomed bucket. Fish captured in gill nets were examined for species, weight, fork length, sex, degree of maturity and scale samples. Stomach samples were taken from some specimens.

(2) Stream and Migratory Fish Survey

Streams tributary to the proposed reservoir were walked to above the flood line and in all streams attempts were made to record species of fish present, water temperature, gravel characteristics, stream gradient, water flow, turbidity, extent of spawning grounds and tree cover. An attempt was made to predict the amount of spawning facilities which will be left after the reservoir is filled. Timing and abundance of rainbow trout, Dolly Varden and kokanee in spawning runs were noted; particular emphasis was placed on the rainbow trout run because of its importance to the Kootenay Lake fishery.

Throughout April and May of 1963, the Lower Duncan River was patrolled by observation from shore, boat, and by swimming, to study fish habits. Attempts were made during each patrol to count large rainbow spawners and to establish their spawning sites either by observing the actual spawning act or by discovering their redds after spawning was completed.

Vantage points were selected overlooking the most favourable spawning sites. These were checked at least once every two days and at various times on each day of observation.

Wildlife

Investigations of wildlife resources were largely confined to habitat mensuration and counting of populations of big game and waterfowl. Abundance of upland game and fur bearers was noted.

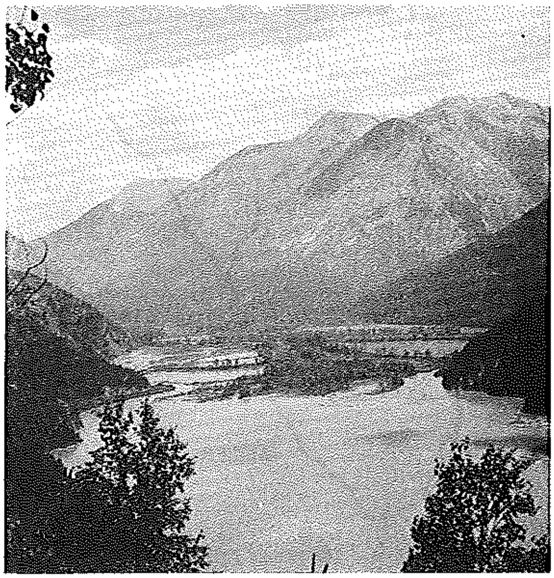
THE DRAINAGE SYSTEM

GEOGRAPHY OF THE DRAINAGE AREA

Kootenay Lake, Duncan Lake and Duncan River lie in the Purcell trench of southeastern British Columbia. The Lardeau River drains Trout Lake and, flowing in a southeasterly direction, is confluent with the Duncan River at a point approximately 6 miles upstream from Kootenay Lake. General geography of the area is shown in Figure 1. Figure 4 shows the extent of flooding of land and stream mouths adjacent to Duncan Lake and rivers.

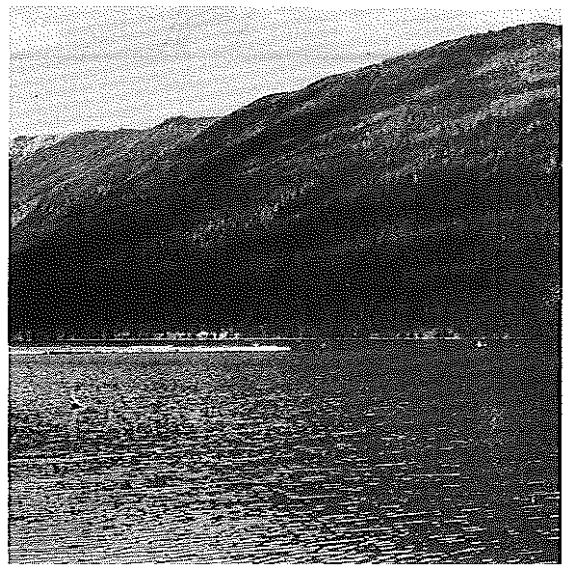
The Duncan Reservoir will occupy about 11,000 acres and will extend 25 miles up the valley from the dam.

The valley to be occupied by the Duncan Reservoir is about 1 mile wide, and is walled by moderately steep mountains throughout most of its length. There are a few areas of moderate slope and relatively flat lands, mainly at the lower end of, and below, the damsite. The valley floor below Duncan damsite contains areas of wetlands, most of which have been partially reclaimed as farmland. Above Duncan Lake, the valley floor is flat and contains extensive wetlands - about 6,400 acres. The upper 6 miles of valley to be occupied by the reservoir is flat (about 3,500 acres).



NORTH END OF DUNCAN LAKE SHOWING

GENERAL TOPOGRAPHY



SOUTH END OF DUNCAN LAKE

SHOWING GENERAL TOPOGRAPHY

DUNCAN LAKE LOOKING NORTHWARD

FIGURE 3. VIEWS OF DUNCAN LAKE

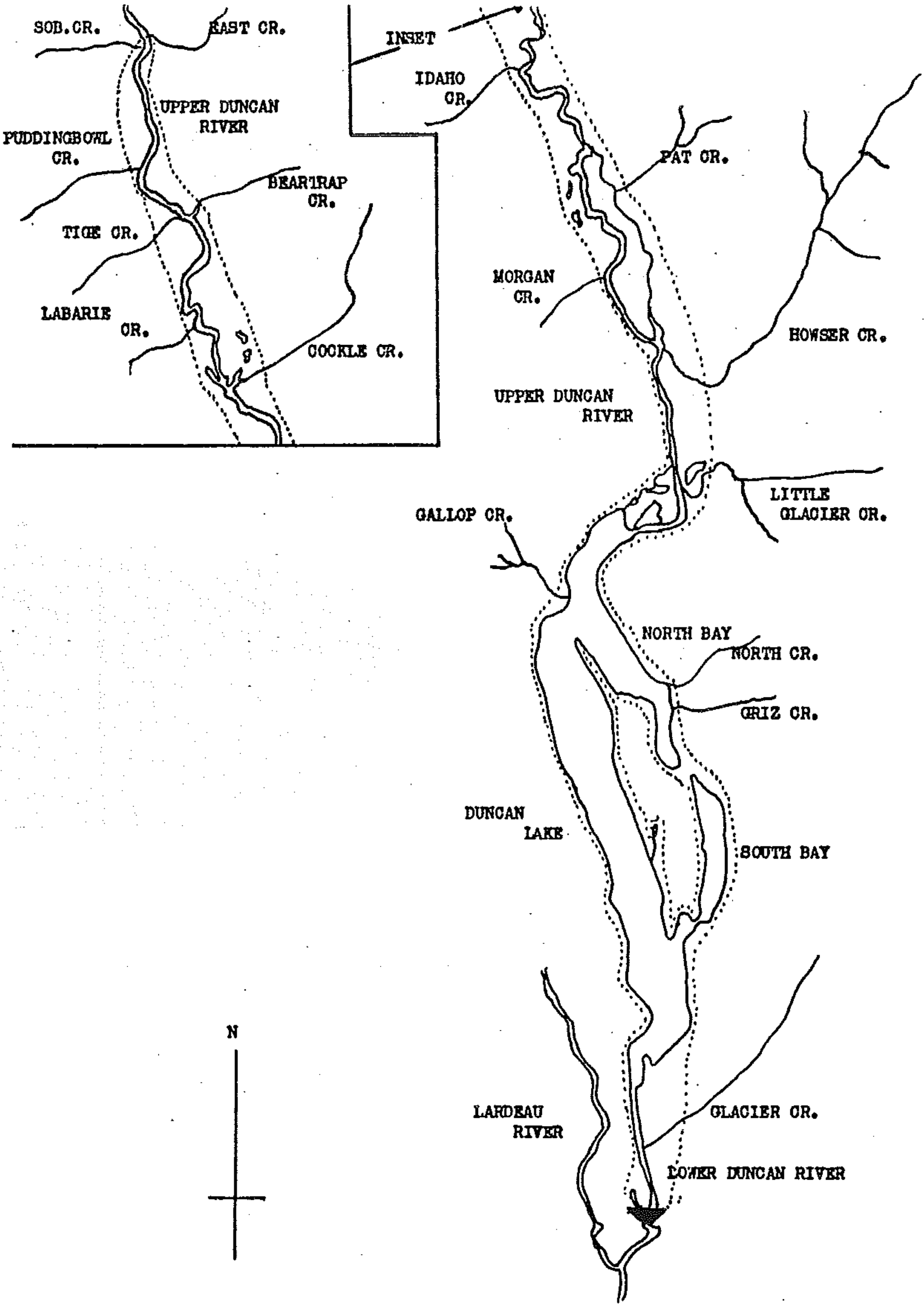


FIGURE 4, The areas of Duncan River, Duncan Lake and Upper Duncan River to be flooded by Duncan dam (maximum reservoir elevation is enclosed by a dotted line).

Vegetation on the valley sides is predominantly conifer cover in varying stages of succession caused by fires and logging. Douglas fir, red cedar, hemlock, spruce, white-pine, and larch occur in various associations. Some "burn" areas support a rich deciduous growth, including willow, amalanchier, prunus, alder, and red osier.

FISH HABITAT AREAS

DUNCAN LAKE

Duncan Lake is a deep, unproductive lake possessing the following physical features:

Length	10 miles
Average Width	0.5 miles
Maximum Depth	385 feet
Mean Depth	169.5 feet
Surface Area	6,519 acres
Volume	1,045,180 acre ft.
Perimeter	202,400 ft.
Shore Development	6.8

TRIBUTARY STREAMS

Duncan River

This river is divided by Duncan Lake into two portions, the Upper and Lower Duncan Rivers. Water flow in Upper Duncan River is formed by a large number of small precipitous streams fed by melt-water from snow fields and glaciers. During spring and summer months the river is highly turbid due to glacial "flour" carried by the water.

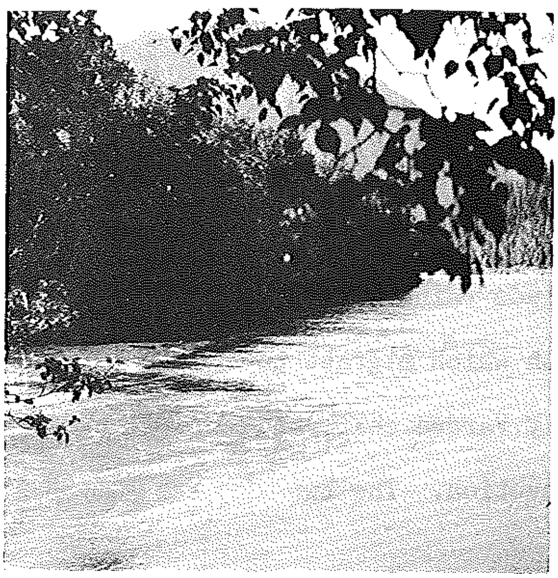
Lower Duncan River, which drains Duncan Lake, is also turbid with glacial silt. Glacier Creek, which flows into the river .75 miles downstream from Duncan Lake, adds considerably to this turbidity. This creek carries a great amount of glacial material throughout the spring and summer (Figure 5). The Lower Duncan River is fairly fast-flowing with few riffle areas.

In most years, both Upper and Lower Duncan Rivers are fairly clear in the winter and early spring. When water begins to rise during the spring freshet period, tributary streams and the main river become turbid. The two rivers and Duncan Lake remain moderately turbid throughout the rest of the spring and summer, and depending on rainfall, into autumn. In 1963, water in both Upper and Lower Duncan Rivers and Duncan Lake remained very turbid later than October 1st. This was due, partly, to extensive logging operations carried out along Upper Duncan River, where log driving was employed in the river. The effects of such an operation are discussed later.

Along both east and west shores of Lower Duncan River, slough areas are connected to the river. These sloughs are excellent rearing ponds for juvenile game fish and they probably contribute much fish food to the river. These sloughs extend from the east bank of the river to the foot of the mountain which will form the east bank of the proposed reservoir, and they extend from the south end of Duncan Lake to the damsite. Thus, on the east

LOWER DUNCAN RIVER
IN SPRING MONTHS

GLACIER CREEK
DURING PEAK FLOW
(NOTE TURBIDITY)



LOWER DUNCAN RIVER IMMEDIATELY
BELOW MOUTH OF GLACIER CREEK (LEFT).
NOTE TURBIDITY EFFECT OF GLACIER
CREEK ON RIVER

FIGURE 5. VIEWS OF LOWER DUNCAN RIVER

side of Lower Duncan River there are approximately 2.5 square miles of flat land which will be flooded. This area contains 1.5 square miles of slough. On the west side of the river a major slough area lies immediately north of the damsite; this contains about .25 square miles of slough.

Duncan River contributes approximately 3/4 of the total volume of water entering the north end of Kootenay Lake from the Duncan-Lardeau drainage.

Lardeau River

The Lardeau River flows 33 miles in a southeasterly direction from its source at Trout Lake to its confluence with Lower Duncan River, about 6 miles north of Kootenay Lake. Its volume is roughly 1/3 that of Lower Duncan River but seasonal fluctuations and temperatures are similar. It is fed throughout its length by glacial streams which contribute to discolouration of the river during the runoff period (May, June, July). The river has a fairly low gradient with alternate riffle areas and pools.

Resident fish in Lardeau River include rainbow trout, Dolly Varden char and mountain whitefish. Fish which migrate to the river to spawn include rainbow trout, Dolly Varden char, and kokanee. These are discussed in a following section. The two factors of gravel location and turbidity appear to limit rainbow trout spawning to a 1/4 mile area between the outlet of Trout Lake and the confluence of the Lardeau River and its first tributary, Mobbs Creek. Dolly Varden and kokanee spawn in the fall when turbidity is low. Dolly Varden spawning areas in Lardeau River are unknown. Kokanee spawn throughout the length of the river; preferred spawning areas are in the uppermost side channels of the river.

LOWER DUNCAN RIVER TRIBUTARIES

Hamill Creek is fairly precipitous from source to mouth, mostly flowing over rocks of 6 - 18 inch diameter. A few pools exist in the lower 1/2 mile of stream but above this point the creek flows through a precipitous canyon where the current is extremely rapid. Above the canyon the current is less rapid and some suitable spawning gravel exists. This canyon is passable to fish. The water is turbid and is cold all year round, never rising above 50° F. Water volumes average 50 - 60 cubic feet per second. No resident fish were found in this stream, but spawning Dolly Varden char were present in late summer and fall months.

Cooper Creek has a moderate gradient. It consists of water flowing over gravel of 3 - 12 inch diameter in most areas, making some of it ideal for spawning purposes. Many pools are present. Water volumes average 60 - 70 cubic feet per second. Dolly Varden char were observed in Cooper Creek in late summer and fall months.

Glacier Creek has a bed of gravel ranging from 1/4 inch diameter to boulders. The lower 1/2 mile of the stream has many areas with gravel of 1 to 6 inch diameter, suitable for spawning. The upper portions of the creek are quite precipitous and unsuitable for spawning. Water temperatures are fairly low all year, seldom rising above 50° F.

The main factor limiting use of this stream as a spawning ground is its high turbidity. Large amounts of glacial "flour" are carried by the creek each year at high water and this continues until late fall. Water flow in August, 1963, was about 100 cubic feet per second.

One pair of Kootenay Lake rainbow trout were observed spawning in the lower 1/2 mile of stream in spring of 1963. No other spawning was observed. Resident rainbow trout and Dolly Varden are present in the upper reaches, well above flood line; these are 6 to 8 inches in length.

Meadow Creek in its lower 2.5 miles of stream course, meanders extensively and has a gentle gradient. The creek has extensive areas of gravel which are heavily used by spawning kokanee. Further upstream, the gradient increases and gravel size is up to 1 foot in diameter. Here, suitable spawning sites are present and are used by Dolly Varden in late summer and early fall.

Aside from kokanee and Dolly Varden which frequent this stream for spawning, resident rainbow trout and resident Dolly Varden char to 8 inches in length are present in the upper reaches.

Kokanee are collected and artificially spawned each year at a trapping site on the lower stream. The eggs are shipped to many places on the North American continent for fish culture purposes.

DUNCAN LAKE TRIBUTARIES

Griz Creek is very precipitous, falling about 100 feet in each 1/4 mile of length. A waterfall about 200 yards from the mouth sets an upstream limit for migrating fish. In this lower portion, the gravel is of 1 to 6 inches in diameter and is suitable for spawning purposes. The water is fairly clear throughout the year. The water temperature on May 27th, 1963 was 45° F. and the flow was about 10 cubic feet per second.

Small resident Dolly Varden char and sculpins are present above the falls.

North Creek contains little spawning gravel and is probably too precipitous for spawning purposes. It falls 100 feet in the lower .15 mile of stream. Water flow averages 5 cubic feet per second.

No fish were captured or observed in this stream.

Gallop Creek is very precipitous, falling its last 100 feet in 1/4 mile. This stream has some small gravel, about 6 inches in diameter near the mouth, but large boulders predominate above this area. The water is very silty throughout most of the year, thus limiting its use for spawning. Stream flows average 5 - 10 cubic feet per second.

No fish were captured or observed in this stream.

UPPER DUNCAN RIVER TRIBUTARIES

Little Glacier Creek is divided into many channels at the foot of the mountain from which it flows. The numerous channels then flow in a meandering fashion .25 mile or more to the Upper Duncan River. The water in these channels is slow moving and the bottom is composed of mud and silt unsuitable for spawning. Above the reservoir flood line the stream is too precipitous for fish spawning. The water is quite turbid throughout most of the year.

Howser Creek flows through a precipitous canyon before broadening out over a gravel plain and dividing into smaller channels which empty into Upper Duncan River. The canyon region is impassable to fish, and accumulated logs and wood debris preclude spawning downstream of the canyon.

A few small rainbow trout, Dolly Varden char and numerous non-sport fish such as suckers, squawfish and sculpins are present in this stream.

Idaho, Maude, Labarie, Tige, Puddingbow, S.O.B. and B. B. Creeks are all extremely precipitous. Very small areas of spawning gravel are present at the mouths of these streams, water flows are small and the streams are turbid.

Some of these streams contain small populations of resident rainbow trout and Dolly Varden char.

WILDLIFE HABITAT AREAS

This section gives the location and approximate extent of the major habitat types in the Duncan Reservoir area. Major wildlife species in the habitat types are noted.

River and Stream Edge

About 140 miles of riparian (streamside) habitat exists in the reservoir area. Evidence of winter use of this habitat by caribou, elk, and deer was noted. Also, beaver, muskrat and mink occur in the riparian areas. Ruffed grouse are common in this habitat.

Open Water Ponds and Lakes (excluding Duncan Lake)

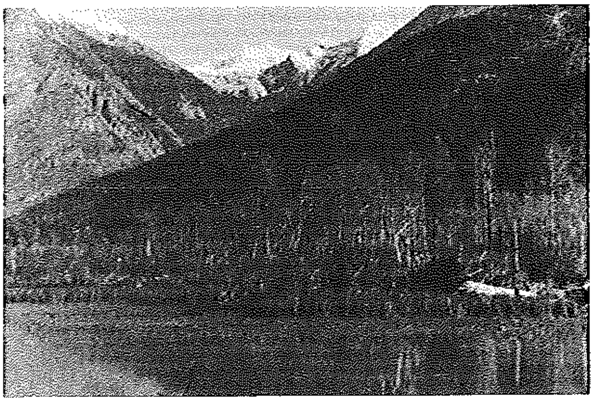
Eighteen permanent open sloughs, 450 acres in extent, exist in the reservoir area. The shores of Duncan Lake contain some 80 acres of a similar habitat. Ducks and geese occupy the ponds as nesting habitat and large numbers of ducks, geese and swans utilize them during spring and fall migration.

Wet Meadows

Some 4,000 acres of wet meadows occur in the reservoir area, much of which are of recent origin caused by beaver impoundments on stream fans. Whitetail deer are numerous in this habitat type and elk, caribou and black bear also use it at various seasons of the year. Mule deer are reported to be present in meadows during spring months, although none were observed in 1963.

Forest Land

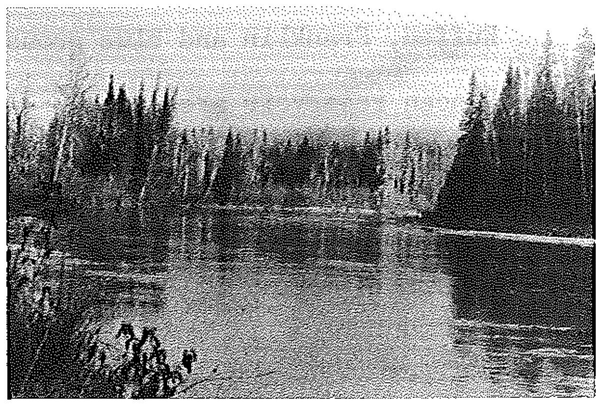
This habitat comprises the upland areas within the flood level of Duncan Dam. Some 6,250 acres exist, which seasonally provide habitat for whitetail deer, mule deer, elk, caribou black bear and grizzly bear. Marten, fisher, weasel and squirrel are probably present in the forest habitat of the Duncan drainage Ruffed, Franklin and blue grouse occupy the upland areas of the Duncan reservoir area.



DUNCAN MARSHLAND -

WATERFOWL, BIG GAME AND

FUR BEARER HABITAT



UPPER DUNCAN RIVER

UPPER DUNCAN RIVER BOTTOM LAND -

EXCELLENT DEER AND BEAVER RANGE

FIGURE 6. Riparian habitat of Upper Duncan River

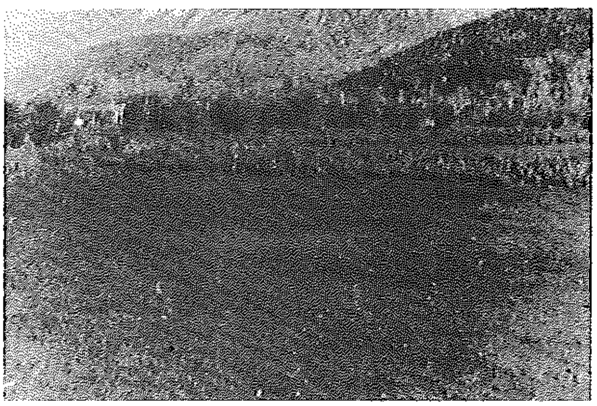
DUNCAN MARSH - WATERFOWL

HUNTING AREA

DUNCAN VALLEY - SHOWING

RELATIONSHIP OF MARSH AND

UPLAND GAME HABITAT



DUNCAN FLATS - WATERFOWL

AND BIG GAME HABIT

GOOSE HUNTER

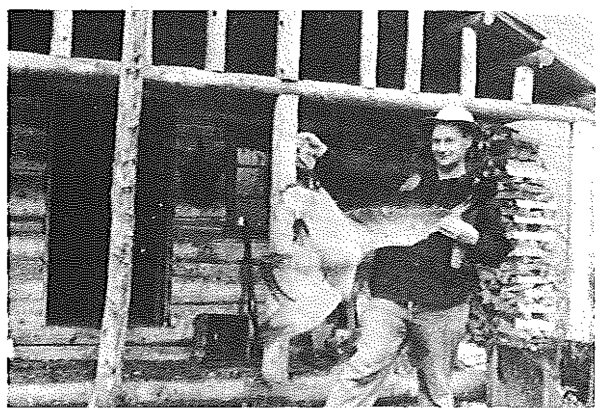


FIGURE 7. Upper Duncan River wildlife habitat

FISHES OF THE DRAINAGE SYSTEM

Rainbow Trout

Figure 8 shows gravel bed areas in Lower Duncan River which were observed during April and May, 1963, for rainbow trout spawning. Because of the high turbidity of the Lower Duncan River, a total count of large Kootenay Lake rainbow trout spawners could not be made. However, 24 of these fish were observed.

Records of fry emergence from spawning gravel are available for 1962 and 1963. In 1962, fry were first observed in Lower Duncan River on July 8 in the vicinity of the proposed damsite. Figure 9 indicates that they appeared immediately after the water level had reached its spring runoff peak and started to decline and when water temperature was between 50° and 60° F. Capture sites are shown in Figure 8.

Four hundred and sixty-nine fry were captured from July 8 to September 20, 1962. The fry increased in size progressively during this period, (Table I). Apparently, most fry remained in the river until the end of August, then began to migrate downstream to pass their first winter in Kootenay Lake.

In 1963, fry were first captured on June 25, two weeks earlier than the first fry capture of 1962. As in 1962, the

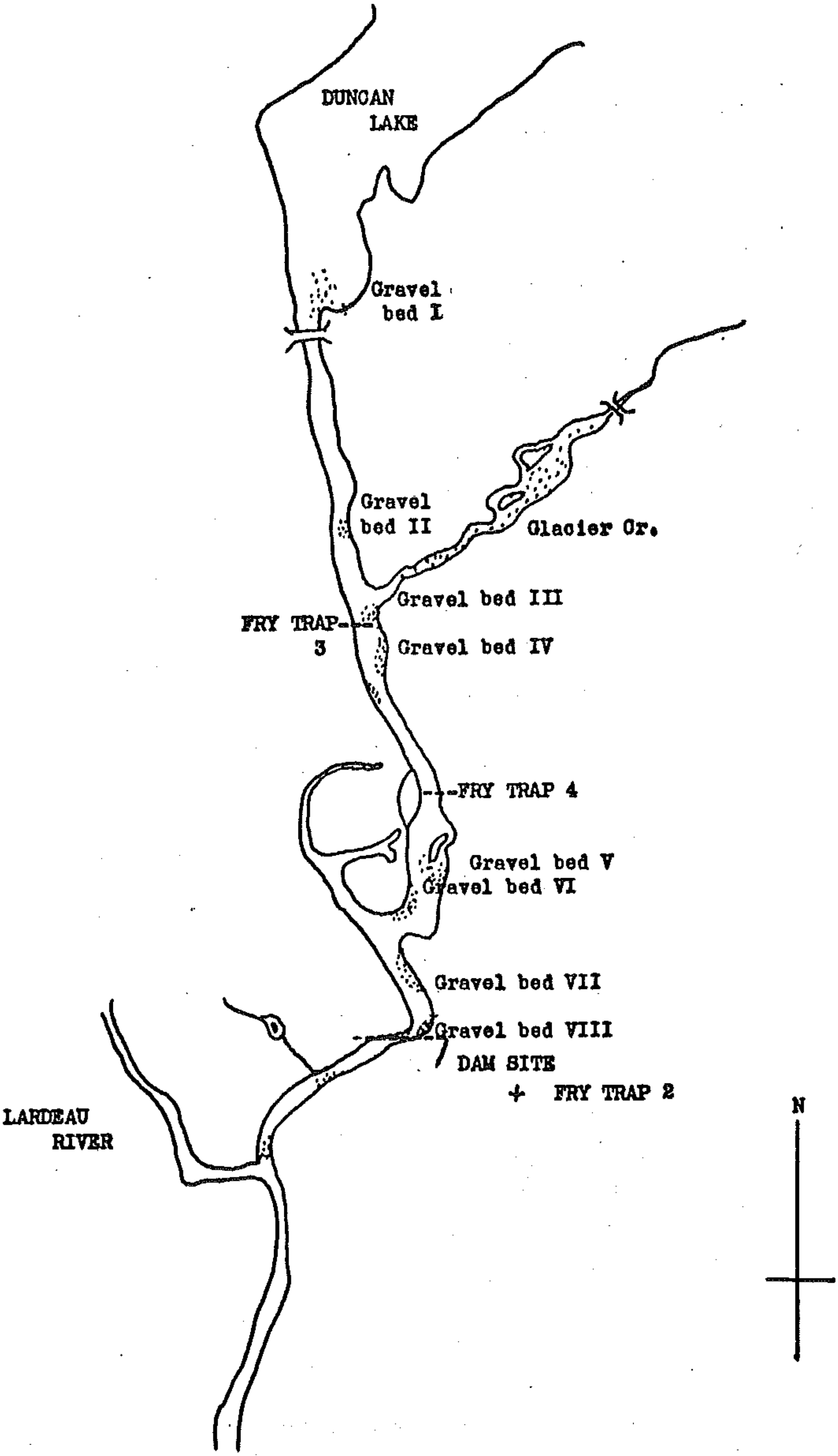


FIGURE 8. Lower Duncan River showing gravel bed spawning areas and fry sampling sites.

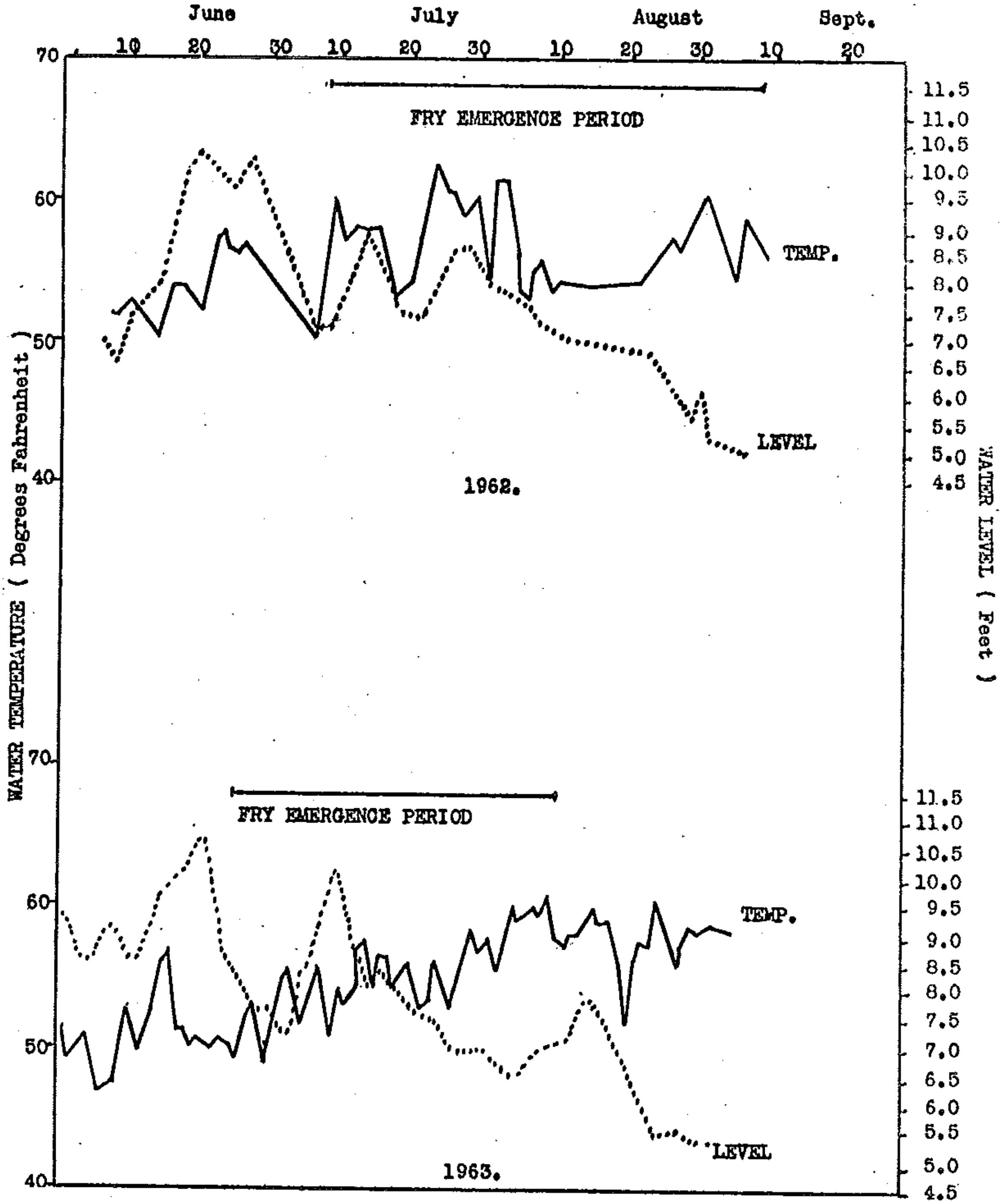


FIGURE 9. Water temperatures, water levels, and rainbow trout fry emergence in Lower Duncan River (1962 and 1963)

Table I. Mean and extreme lengths of rainbow trout fry captured in Duncan River at different time periods, July to September, 1962.

SIZE OF FISH (millimeters)

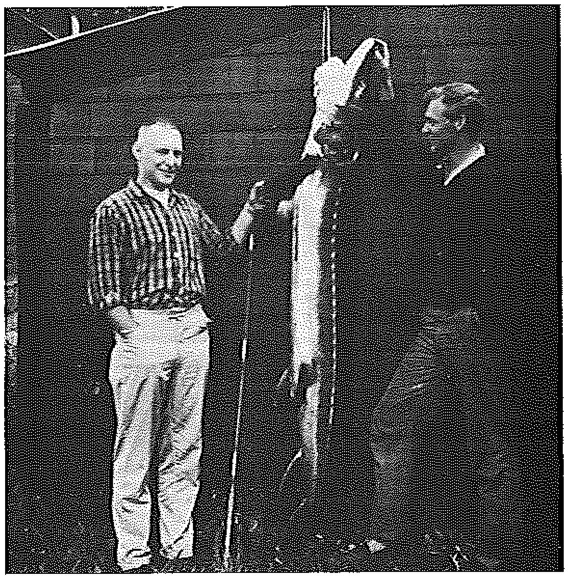
TRAPPING SITES*	July 8-14		July 15-31		Aug. 1-14		Aug. 15-31		Sept. 1-17	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
1	—	—	30.0	—	35.4	29-44	43.9	41.5-48	—	—
2	—	—	34.3	26-43	38.3	28.43	47.7	40-66	—	—
3	—	—	34.1	26-42	—	—	—	—	—	—
4	29.9	25.5-35	30.3	25.34	40.3	36-46	46.6	41.5-54	55.3	47.64
5	—	—	32.7	28-35	35.0	—	48.5	—	—	—

* Trapping sites are increasingly distant downstream from Duncan Lake

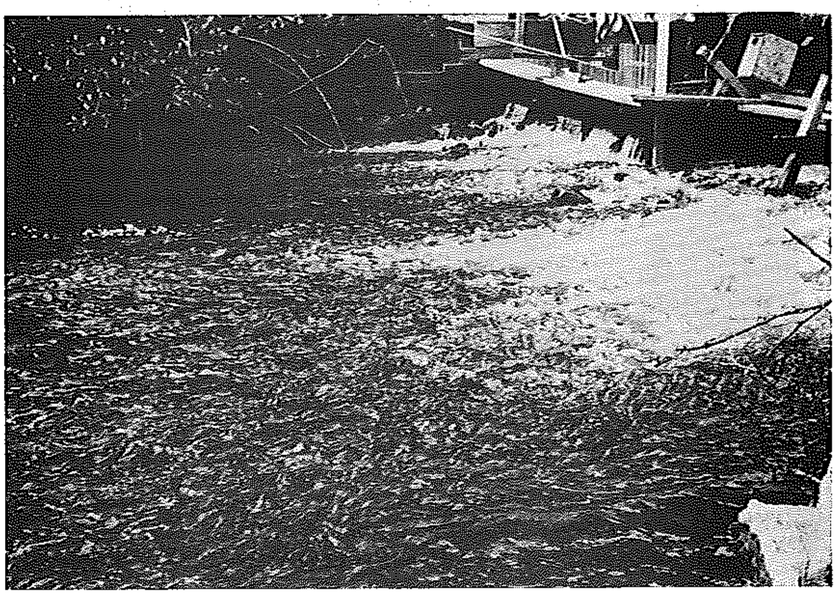
Table II. Mean and extreme lengths of rainbow trout fry captured in Duncan River at different time periods, June to August, 1963.

FRY* TRAP NO.	June 25 – July 1		July 2-8		July 9-15		July 16-22		July 23-29		July 30 – Aug. 8	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
3	28.5	27-30	29.5	29-30	30	30			27	26-28		
4	28.5	25-32	30.0	26-34	28	28	42	36-48	27	22	35	35
Fyke Net #3			31.5	31-32								
2	31.5	25-38	29.5	26-33					45	45	56	56
Laney's Slough							39.5	36-43			52	52

* See Figure 9 for locations of fry traps.



A 147 LB. WHITE STURGEON FROM DUNCAN LAKE



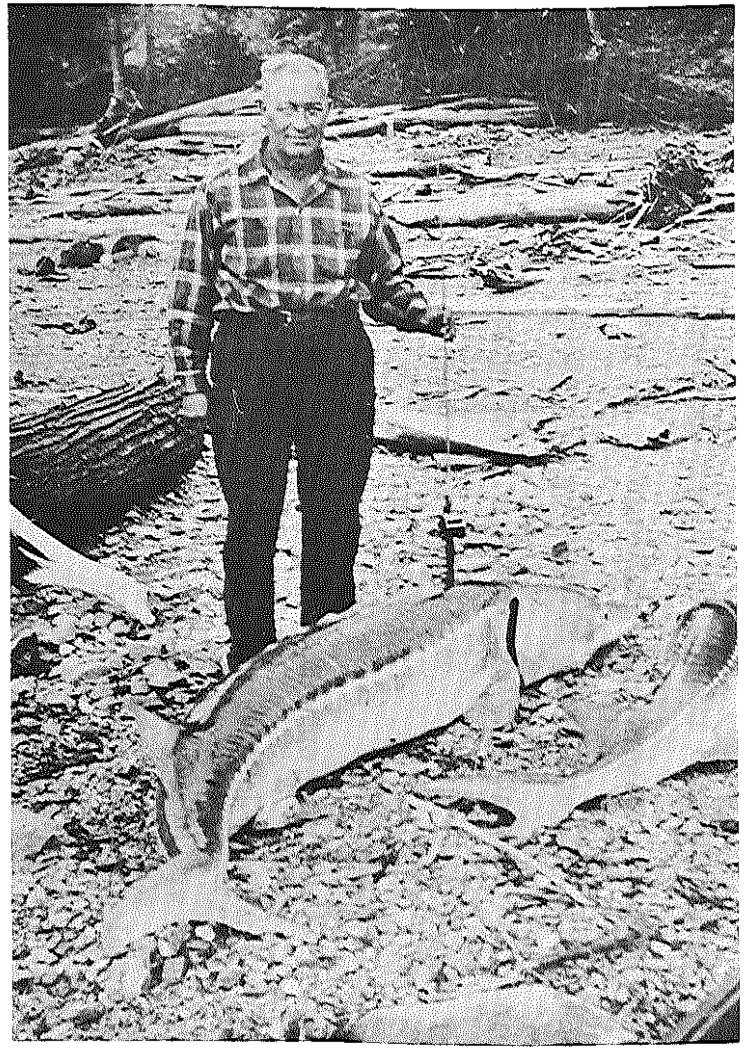
MEADOW CREEK KOKANEE SPAWNING MIGRATION FROM KOOTENAY LAKE

FIGURE 10. Some fishes of the Duncan-Kootenay system

KOOTENAY LAKE RAINBOW TROUT - ABOUT 20 LBS.
(B. Blackmore Photos)

FIGURE 11. Some fishes of the Duncan-Kootenay system

A 19 LB. AND A 9½ LB. DOLLY VARDEN CHAR FROM LOWER DUNCAN RIVER



A 300 LB. AND A 110 LB. WHITE STURGEON FROM KOOTENAY LAKE AT MOUTH OF LOWER DUNCAN RIVER (Rutherglen Photos)

FIGURE 12. Some fishes of the Duncan-Kootenay system

1963 fry first appeared immediately after the first decline from peak water flows. Water temperature was above 50° F. (Figure 9). In 1963, only 147 rainbow trout fry were captured. Trapping records indicate that all fry had left the river shortly after the end of August.

Dolly Varden Char

There are spawning runs of Dolly Varden char in Hamill, Cooper and John Creeks, and Lower Duncan and Lardeau Rivers which are of importance to the Kootenay Lake fishery and to the local river sport fishery. These spawning fish are probably from Kootenay Lake.

In 1962, Dolly Varden char comprised 33.4 percent of all fish angled in the north and south arms of Kootenay Lake. These fish averaged 57.4 cm. in length and 2.3 kg. in weight (22.5 inches; 9.1 lbs.). In Lower Duncan River the Kootenay Lake migrants remain temporarily in pools immediately below the mouths of Hamill Creek and Cooper Creek and mature fully before moving upstream to their spawning beds in these creeks and in Duncan and Lardeau Rivers. There are still enough fish in these pools at the opening of the fishing season in the river (September 1) to attract a great many anglers who angle not only for spawners going upstream but also for kelts (spawned-out fish) moving back down the river to Kootenay Lake. About 100 anglers were counted at the mouths of Hamill and Cooper Creeks on Labour Day weekend of 1963. Fishing continues in the Duncan and Lardeau Rivers throughout the winter until the river is closed to fishing on April 1.

Kokanee

Very large numbers of kokanee (landlocked sockeye salmon) frequent the Duncan-Lardeau River system for spawning. The adults first appear in the rivers in late August or early September and spawn in September, October and November. They die after spawning. These fish provide an important food source for rainbow trout, contribute an important sport fishery to Kootenay Lake, and provide eggs (from collections at Meadow Creek) for fish culture throughout North America.

Other Species

Other species of fish known to be present in the Kootenay Lake-Duncan River-Duncan Lake system are listed below:

Mountain whitefish	-	*Prosopium williamsoni*
Pygmy whitefish	-	*Prosopium coulteri*
White sturgeon	-	*Acipenser transmontanus*
Burbot or ling	-	*Lota lota*
Largescale sucker	-	*Catostomus macrocheilus*
Finescale sucker	-	*Catostomus catostomus*
Northern squawfish	-	*Ptychocheilus oregonensis*
Redside shiner	-	*Richardsonius balteatus*
Peamouth chub	-	*Mylocheilus caurinus*

Longnose dace - Rhinichthys cataractae

Slimey sculpin - Cottus cognatus

Potential fisheries of some magnitude exist for whitefish, ling and sturgeon in the Duncan Lake and river system; however, these species are presently only lightly exploited.

THE KOOTENAY LAKE SPORT FISHERY

Construction of a dam on Duncan River will adversely affect the sport fish production of Kootenay Lake. A brief description of this unique and important fishery follows:

A race of exceptionally large rainbow trout exists in Kootenay Lake, with fish weighing 20 pounds not uncommon; and rainbow trout up to 30 pounds have been caught. The Lardeau River is the major spawning stream for these fish; the most important spawning area is between Mobbs Creek and the outlet of Trout Lake, in the upper 1/4 mile of the Lardeau River. Duncan River contains a spawning area of lesser importance. Angling for these fish has always been popular and creel census reports indicate that fishing success and pressure have increased over the last few years.

Kokanee also contribute substantially to the Kootenay Lake sport fishery (Sparrow, 1962, 1963), for example:

TABLE III. Some kokanee measurements from creel census records, 1962 and 1963.

Year	Number Caught	Length (cm.)	Weight (kg)
1962	1,677	24.68	0.186
1963	4,758	No data available (but kokanee observed to be larger)	

SPORT-FISHING EXPENDITURES FOR KOOTENAY DISTRICT

In 1958, J. H. Gee, at the request of the Fish and Game Branch, prepared an estimate of money spent on angling in the Kootenay district of British Columbia. This estimate was obtained from information volunteered by licence holders replying to a standard questionnaire. The licence holders receiving a questionnaire were selected at random from residents of B. C., non-resident Canadians, and non-resident Americans. Of a total of 24,270 licences sold in the Kootenay district, 938 were sampled, from which 266 replies were received.

Gee estimated the total expenditures for the Kootenay district to be $1,547,080.00 or $103.07 per angler in 1958 for resident anglers; $211,395.00 or $55.91 per angler for non-resident Canadian anglers; $170,985.00 or $61.55 per angler for non-resident American anglers. This gives a total expenditure of $1,929.462.08 or $89.45 per angler spent by all licence holders on sport fishing in the Kootenay district.

It was found that 41.3 percent of resident licence holders fished Kootenay Lake, also 14.3 percent of the non-resident Canadians, and 80 percent of non-resident Americans.

A total of 42 percent of all licence holders fishing in the Kootenays fished mainly in Kootenay Lake and sport fishing in Kootenay Lake resulted in an expenditure of about $810,000.00 in 1958.

Creel census studies on Kootenay Lake indicate that fishing pressure (number of hours fished) has about doubled in 1963 from the 1958 figure. It is reasonable to assume that the expenditure on sport fishing has increased by a similar proportion. This, then places a value of about $1,600.000.00 on the Kootenay Lake sport fishery in 1963. This figure does not include an important fishery for rainbow trout and kokanee in the "west arm" of Kootenay Lake.

TABLE IV. Creel census data for Kootenay Lake sport fishing for years of available records, 1953 to 1963. (Cartwright, 1961).

Year	Total Hours Fished	Total Fish Caught	Avg. Catch/hr. All Fish	Avg. Catch/hr. Rainbow Only
1953	25,232	3,306	0.13	0.086
1954	34,444	5,547	0.16	0.106
1955	17,512	4,188	0.24	0.16
1956	20,000	3,200	0.16	0.105
1957	11,495	4,503	0.39	0.32
1958	8,535	5,456	0.64	0.46
1959	23,763	8,003	0.34	0.20

Year	No. Anglers	Hrs. Fished	Total Fish	Rainbow	Catch/hr. Rainbow Over 5 lbs.
1962	9,857	41,235	5,237	2,331	0.056
1963	12,633	52,076	8,366	2,990	0.057

These creel census reports show a progressively increasing mean size for rainbow caught during the years previous to 1962. A creel census survey in 1963 shows a further size increase in the fish caught in that year.

A progressive increase in size of fish and catch per hour contribute substantially toward making Kootenay Lake an increasingly popular fishing area for tourists and for residents of the area.

WILDLIFE OF THE DRAINAGE AREA

Big game animals, fur bearers and waterfowl were observed in the Duncan Reservoir area in 1963. Only in some few instances was it possible to obtain population estimates.

Big Game

Seven elk were seen in the upper Duncan marshes in May and evidence of this species was observed throughout the reservoir area. An extensive burn in the vicinity of Howser Creek may winter a substantial population of elk; perhaps 100 head, most of which probably use the reservoir area seasonally.

No evidence of the presence of moose was seen in the reservoir area but there are reports of moose in tributaries to the east of Upper Duncan River. Goat are known to occur along the Upper Duncan valley, and one area of concentration close to the reservoir level is between Duncan Lake and Howser Creek. No estimate of population numbers is possible. Caribou are commonly taken by hunters in the Upper Duncan reservoir area. Considerable evidence of spring use of the marsh area was observed; however, there is little quantitative basis for an estimate of numbers. Possibly about 50 caribou occupy the upper drainage periodically. Much evidence of the presence of black bear was found in Upper Duncan reservoir area. The population which periodically lives within the marshes is believed to be in the order of 25 animals. Grizzly bear are relatively common in the Upper Duncan drainage. One specimen was seen during the course of studies and evidence of the presence of grizzly bear was noted throughout the area. A population of about five is assumed to seasonally frequent the reservoir area.

Fur Bearers

Beaver are common in all wetland areas. There is little factual basis for estimating numbers but on the basis of area and quality of habitat a population of about 1,000 probably occupies the reservoir area.

Probably about 2,000 muskrat occupy the wetlands in the reservoir area.

Evidence of the presence of mink is common in riparian habitat in the reservoir area. No estimate of numbers can be made.

Otter probably occur in the Duncan system. No evidence of the species was found.

Marten were not observed; however, this species undoubtedly occupies upland areas in and adjacent to the reservoir area. No estimate of numbers is possible.

Weasels were not seen in the reservoir area although they are probably present in the Duncan drainage. No estimate of numbers is possible.

Squirrels were commonly found throughout the Duncan reservoir area. No estimate of numbers is possible.

Waterfowl

Geese were observed nesting in the Upper Duncan marshes but there are no data to indicate the size of the nesting populations. Spring and fall counts of up to 1,000 geese were made in the Upper Duncan marshes; probably 5,000 geese migrate through the area.

Ducks nest in numbers in the Upper Duncan marshes and observed spring and fall migrating populations numbered from 3,000 to 4,000 ducks. The nesting population probably numbers at least 1,000 pairs, and numbers of migrating birds passing through the area approximates 50,000 ducks.

Small groups of whistling swans were seen in May and October in the Upper Duncan area. Probably several hundred periodically use the area during spring and fall migration.

Upland Game

Ruffed grouse are common in the reservoir area, associated with riparian and deciduous cover on the valley floor.

Blue grouse probably occur in upland areas of the reservoir, although none were observed during 1963.

Franklin grouse probably occur in upland forest habitat although none were observed in the reservoir area.

EFFECTS OF DAM CONSTRUCTION AND OPERATION

EFFECTS ON AQUATIC POPULATIONS

Physical Effects

Duncan Lake

As far as is presently known, water will be stored in Duncan Lake from May 1 to approximately September 1 of each year, reaching a maximum pool elevation of 1,892 feet by July. After September, pool elevation will drop at a fairly steady rate until maximum drawdown is reached at an elevation of 1,800 feet by May 1. A similar cycle will be continued after installation of power equipment at Mica Creek damsite except that the full pool elevation will be between 1,860 feet and 1,880 feet.

The factors influencing the temperature characteristics of both the reservoir and the tail-water include temperature and volume of inflowing water, depth of reservoir, weather conditions, flow regime of reservoir discharge and level of discharge. These factors interact and consequently make any prediction of temperatures within the reservoir and Lower Duncan River extremely difficult. However, some general predictions can be made. Because the dam is to be used for storage only, with water stored in the spring and summer with little discharge during this period, thermal stratification will result. There will be a constant drain of cold "bottom" water which will result in a lowering of the thermocline and a general warming of the reservoir. Maximum water temperatures will increase because surface water will not be drawn off and the depth of the warmer stratum will be greater. Present Duncan Lake profiles are shown in Figure 13.

Another change will occur after impoundment. Water from Upper Duncan River will be colder than the reservoir itself; hence upon entering the north end of Duncan reservoir it will tend to "dive" under the surface waters of the reservoir to a depth which approximates its own density; because the Upper Duncan River is very heavily silt-laden and therefore more dense than clear water of the same temperature, it will dive to a depth greater than that of its own temperature. This will create a moving mass of cold water through the reservoir--a so-called "density current". Ellis (1940) found that these moving masses of water differing in temperature and density from the surrounding media eddy at great depths and contribute to a highly complex thermal structure. Apparently, movement of the density currents combined with the shape of the basin and regime of discharge result in a reservoir whose regions of specific temperature and oxygen concentration are "hardly predictable".

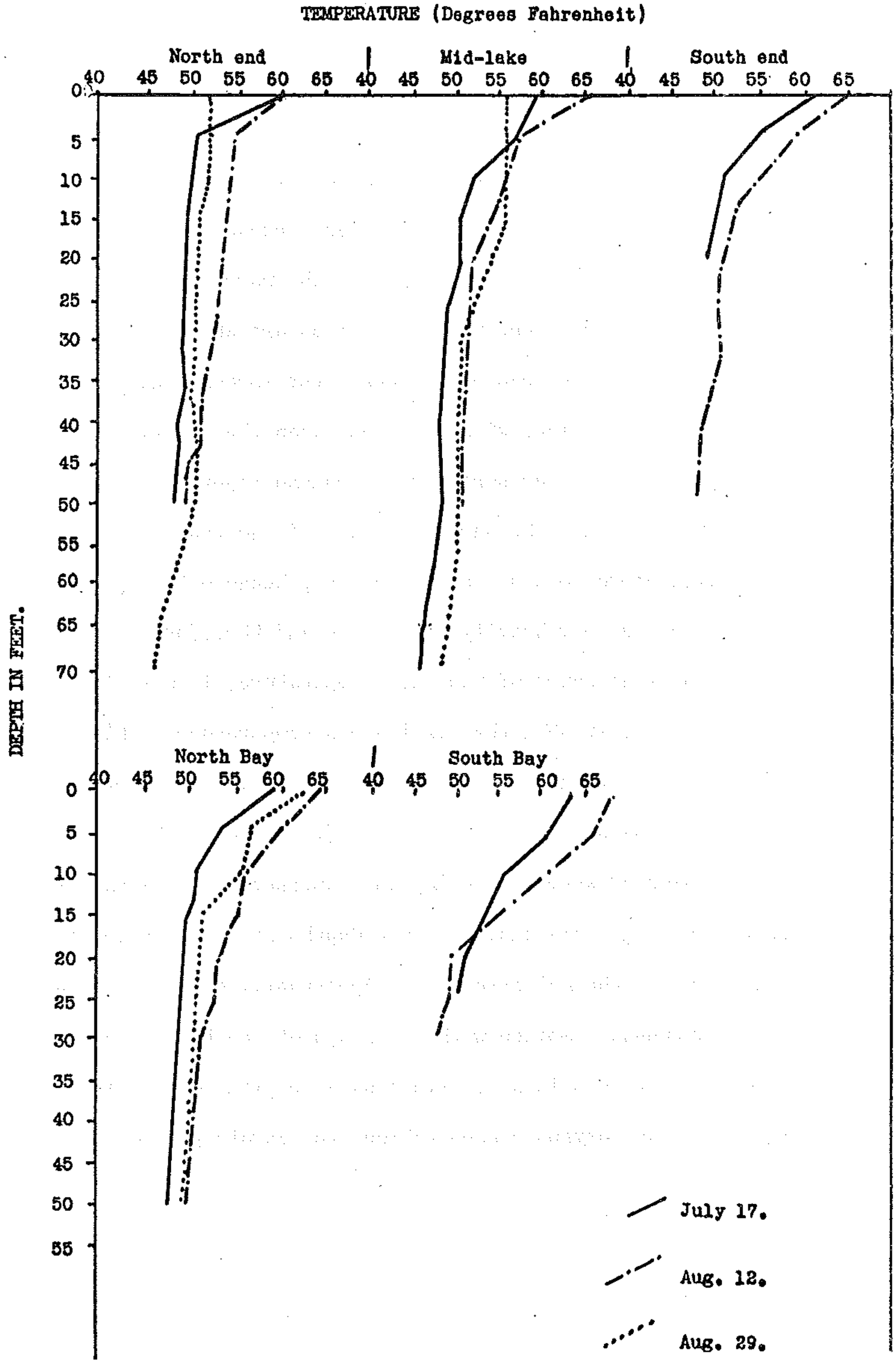


FIGURE 13. Duncan Lake water temperatures (1963)

As far as the density current from the Upper Duncan River is concerned, one of two things could occur to affect temperature of reservoir and tail-water; (1) the current could retain its identity throughout the length of the reservoir and, if it constituted the bottom stratum, it could become the prime contributor of the discharge flow, or (2) it could constitute only a small portion to the entire discharge flow at certain times of the year. This latter possibility is dependent upon two factors--the level to which the density current sinks and the rate at which sediment settles out of this density current (thus reducing its density).

If the Upper Duncan River density current does retain its identity through the reservoir as a cold, sediment-laden water mass, then these two factors become highly important in predicting tail-water temperatures at different times of the year. The level which this current maintains in the reservoir will determine when it will be discharged and when it will affect (markedly decrease) tail-water temperatures. The rate at which sediment settles out will determine the density of the current (and therefore its level) while the temperature remains the same.

Figure 13 shows how Duncan Lake temperature profiles vary throughout a season.

Alternately, water from Upper Duncan River may become thoroughly mixed with Duncan Lake water before reaching the dam and thus lose its identity. If this should happen any prediction of the thermal characteristics of the reservoir is still hazardous. Ellis (1940) points out that since the outlet elevation of a reservoir and that of a natural lake are often different, the temperature pattern of a reservoir is often distinctly different from year to year. While thermal characteristics of a natural lake are often predictable and relatively similar at the same time each year, the temperature characteristics of a reservoir can change abruptly during drawdown.

Because Duncan dam will slow the current of Upper Duncan River through the reservoir appreciably when the turbidity of river water will be greatest (May, June, July, August) there will be an increase in <u>sedimentation</u> in the lake as compared to pre-impoundment conditions, but decreased <u>turbidity</u> of reservoir water due to this settling effect. Sedimentation and turbidity adversely affect fish eggs and fish at all stages of development. The effect of siltation on fish eggs will be discussed in a later section (see Lower Duncan River).

Effects on fish may be "direct" through gill clogging or "indirect", through smothering of fish-food organisms. Concentration of inorganic materials must be very high before death is brought about by gill clogging. Warren (1951) found that 75,000 - 200,000 p.p.m. of silt, a condition very rarely found in nature, could be fatal.

Indirect effects of fish survival and growth are of greater significance. The survival and growth of fish is influenced to a great extent by the availability of food supply. Consequently, by affecting food supply, turbidity and siltation can indirectly alter the survival and growth of fish. This can be done in several ways: by smothering bottom fauna, by reducing primary productivity or by reducing the efficiency of fish in obtaining food.

A smothering effect will occur in the following way. The suspended materials in the reservoir behind the dam will sink to the bottom due to reduction in current speed. This sediment will blanket the reservoir bottom with a layer of silt to a greater extent than at present. This will tend to suffocate bottom fauna populations and prevent maximum utilization by fish food of terrestrial organisms newly covered with water within the flooded reservoir. It has been shown that an initial increase in fish size immediately after reservoir flooding is due to a great extent to the use of terrestrial organisms as fish food. Any prevention of such a contribution would seriously limit this initial size increase. Further, any organic fines deposited on the bottom may have a substantial O_2 (oxygen) demand and thus contribute to an O_2 depletion in the lower strata. The ability of settling material to carry with it to the bottom finely dispersed organic matter has been shown by Bartsch (1954). He has found that gases are given off by such deposits of decomposable organic material. This is an indication of excessive O_2 consumption, a condition unfavourable to fish life.

The effect of turbidity and siltation on primary productivity is due to the ability of suspended particles to absorb radiant energy in the upper water layers, thus reducing the depth of effective photosynthesis. A reduction in photosynthesis results in a reduction in production of algae and other phytoplankton which are part of the food chain for many sport fish, and for larger organisms on which fish feed. Such a relationship between turbidity and productivity was shown in the Missouri River (Anon. 1954). Prior to erection of major dams on the Missouri River, the river was relatively unproductive of phytoplankton. After dam construction, the water was less turbid and had a greatly increased growth of photosynthetic life (algae). Below one dam a 20-fold decrease in turbidity was parallelled by a 10-fold increase in phytoplankton production.

In summary, fishes (kokanee) which dwell in upper waters of the reservoir and feed upon plankton should benefit through increased primary productivity. Dolly Varden, feeding upon a variety of food forms (small fish and bottom fauna) may experience little change in growth rate. Rainbow trout probably will exhibit decreased growth rates because of annual inundation and dehydration and smothering of areas most productive of bottom dwelling organisms (their major food source).

Upper Duncan River

Until installation of power generation facilities at Mica damsite, the reservoir will be drawn down prior to May to elevation of 1800' and should fill to maximum pool elevation of 1892' by July of each year. At minimum pool elevation the reservoir will occupy the same area as the present Duncan Lake. The period of filling each year will require three months and will extend the lake by a distance of approximately 16 miles over a part of the Upper Duncan River which has much gravel which may presently be used for spawning purposes. If this river is used for spawning by spring spawning fish (i.e. rainbow trout) any eggs laid in the spring will be under about 92 feet of water before they hatch, and fish that normally lay their eggs in the Upper Duncan River during the months of August, September, and October (Dolly Varden, kokanee, whitefish) will find their spawning grounds submerged in a great depth of still water. Successful spawning cannot take place under these new conditions.

To date, natural glacial erosion and logging on the Upper Duncan River have had serious effects on spawning potential. A river water sample revealed a silica content of 43 p.p.m. on August 11, 1963, and 220 p.p.m. on August 13 after a rainstorm. Increased soil erosion from logged-off land has resulted in increased turbidity of the Upper Duncan River. Log driving has added to turbidity by physical action of logs against the river bottom and the river banks. Wood chips, bark and sawdust have become suspended in the water, adding to turbidity. This problem has been magnified by removal of river bank vegetation to prevent trapping of logs floating within the river. Physical damage to gravel beds has resulted from action of logs against the bottom, displacing spawning gravel. The extent of this action is dependent upon depth of water over gravel beds in relation to size of the logs. Gravel has also been displaced in efforts to remove logs stranded on gravel bars. Probably, eggs have been destroyed by operation of the equipment necessary for this log removal.

The effects of logging and resulting sedimentation on bottom fauna has been studies in a North Carolina Appalachian watershed by Tebo (1955). He found that pools and riffles downstream from a logged watershed were covered with a layer of unproductive sand and micaceous material. When sedimentation of this type was greatest, the crop of bottom fauna was drastically reduced in comparison to unaffected habitats upstream.

If turbidity continues to increase, it will have an increasingly adverse effect on fish in Duncan reservoir.

Lower Duncan River

Construction of Duncan Lake dam and subsequent water storage and release will alter the flow regime of Lower Duncan River. Presently, water flows are greatest in June with a progressive decline until March, when volumes again increase until a maximum is again reached in June.

Because downstream water requirements and climatological conditions are difficult to predict from year to year it is impossible to estimate with any degree of accuracy the effect of the Upper Duncan River flow regime on reservoir and tail-water characteristics. Table V and Figure 14 show approximate flows anticipated in Lower Duncan River in "normal" years and following dam construction.

Table V. Present and predicted waterflows in Upper and Lower Duncan Rivers from 21 years of waterflow records.

Month	Predicted Mean Flow For Upper Duncan River For Normal Year (estimated from Lower Duncan River discharges) C.F.S. +	3 Year Average Mean Flow of Glacier Creek C.F.S. +	Monthly Discharge From Live Stored Water (normal year) C.F.S. =	Tailwater Flow In Normal Year of Dam Operation C.F.S.
January	575	57	2850	3482
February	494	64	2850	3408
March	519	46	2850	3415
April	1,252	108	2850	4210
May	5,000	368	Storage	1000
June	10,700	1256	Storage	1000
July	9,400	1021	Storage	1000
August	5,490	860	Storage	6360
September	2,860	393	2850	6103
October	1,767	160	2850	4777
November	1,082	106	2850	4038
December	764	78	2850	3692

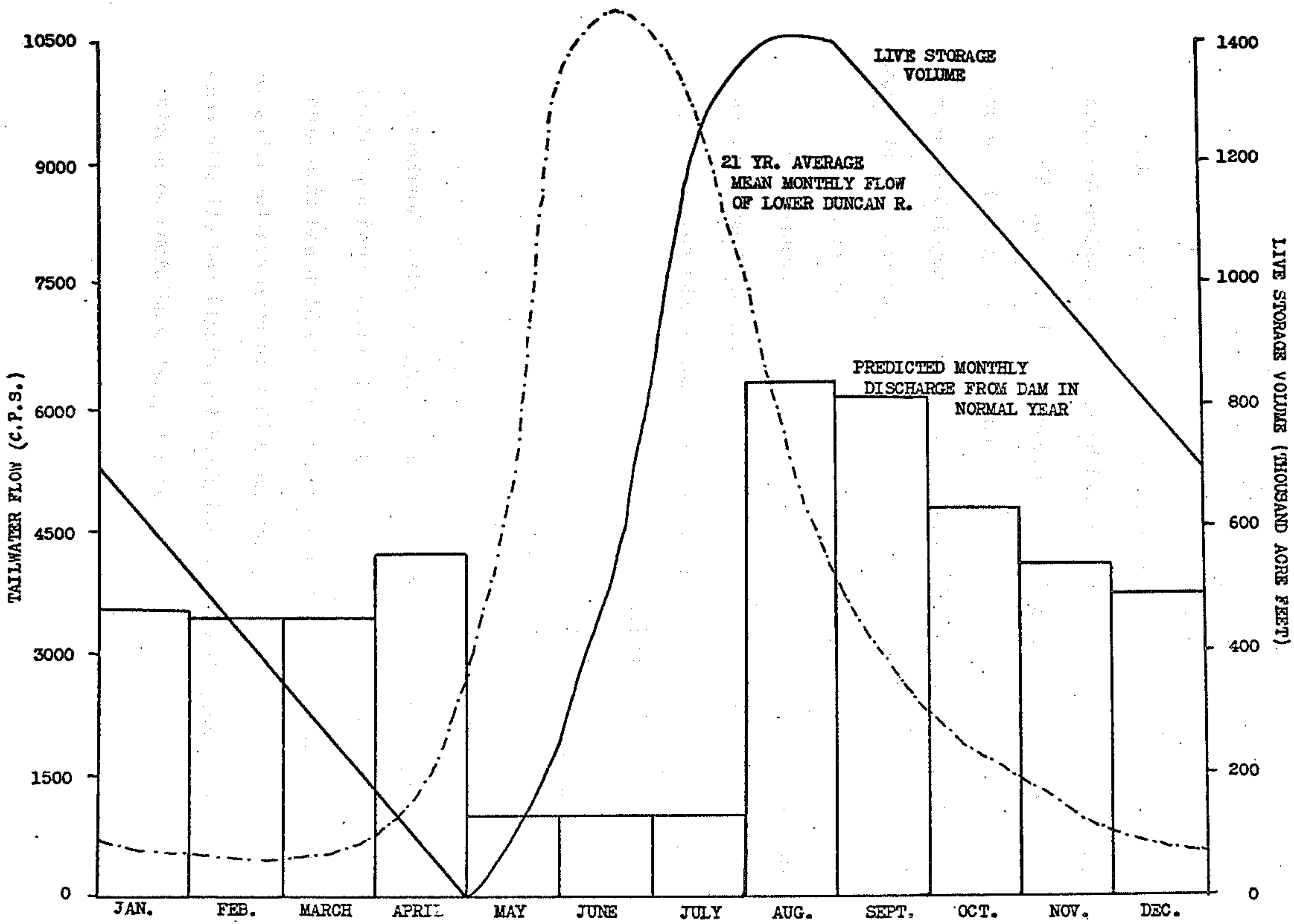


FIGURE 14. Present and predicted waterflows in Lower Duncan River from 21 years of record.

A maximum full pool elevation of 1,892 feet would be obtained by holding back the spring and summer high flows, creating a maximum live storage capacity of 1,400,000 acre feet. This will be released as required by the United States for power requirements, probably in late summer or early autumn. This water will be released at a fairly uniform rate until the reservoir is drawn down to a minimum pool by May 1. Regulated water releases will have the effect of "smoothing out" the present range of mean monthly water flows. Presently, extreme low and high mean monthly flows of 494 and 10,700 c.f.s. are recorded for February and June; with controlled water release these extremes may approximate 1,000 c.f.s. during summer months and about 6,200 c.f.s. in fall months.

Chemical Effects

Duncan Lake

The chemistry of lake and reservoir waters is of prime importance in determining their productivity. Northcote and Larkin (1956) in a study of 100 B. C. lakes found a positive correlation between dissolved solids and plankton and fish abundance while Rawson (1958) has found that in some smaller lakes in Western Canada, favourable "edaphic" (chemical) and climatic conditions may overcome adverse morphological conditions to provide moderate biological productivity. This, however, did not hold true with extremely large lakes such as the Great Lakes or those in the Northwest Territories. This section will discuss predicted changes in chemistry of the water of Duncan Lake reservoir and Lower Duncan River.

The capacity of water to hold oxygen in a dissolved state varies inversely with the temperature of the water. Since the surface water of Duncan Lake will be warmer during summer months after impoundment than at present, its ability to hold dissolved oxygen will be reduced. The cooler water from lower levels will contain more dissolved oxygen per unit volume than will surface water. This tendency towards chemical stratification will become more pronounced after impoundment due to greater warming of the surface water from a greatly increased surface area and from retention of warm upper water of the reservoir.

A more acidic condition of reservoir waters is anticipated for the first years of impoundment as newly inundated acidic forest soil is leached. A change in the pH of the water may alter the species of organisms present within the reservoir.

Generally, a low total dissolved solid (T.D.S.) content in lake water induces relatively low biological productivity. The T.D.S. of the waters of Duncan reservoir may increase after impoundment due to leaching of nutrients from flooding of onshore areas. This will be a temporary condition; flushing of reservoir water will return the concentration of dissolved solids to normal, or near normal, in a few years. Several inorganic elements will temporarily become more abundant through leaching following reservoir filling.

Lower Duncan River

Chemical changes in Lower Duncan River following establishment of a reservoir at Duncan Lake should reflect the changes which take place in the latter body of water.

Biological Effects

Duncan Lake

Primary productivity may be defined as the rate at which energy in the form of organic substances can be stored by photosynthetic and chemosynthetic activity of producer organisms. Producer organisms are phytoplankton and larger green plants in a body of water. In oligotrophic lakes such as Duncan, the most important energy producers are nanoplankton. These organisms are at the bottom of the food chain which ultimately provides food for fish and are therefore of prime importance. Any factor affecting the survival and growth of these organisms will ultimately affect the survival and growth of fish.

An increase in primary production in the reservoir can be expected for the first few years of impoundment. This will be due to the increased nutrient supply from the newly inundated land, plus increased clarity from sediment settling in the upper end of the reservoir. Little net chemical change will be observed as these nutrients will be quickly assimilated in fish and food organisms, and will be lost through "flushing" of reservoir water. Another cause of nutrient loss, suggested by Murphy (1962) is "bacterial utilization of stored energy of drowned vegetation which is exhausted in a few years".

During drawdown, water will be taken from well below the surface of the reservoir. This will remove nutrients and lower the thermocline. The volume of the epilimnion (upper water layer) may remain the same during storage and drawdown but due to decreased lake surface area resulting from drawdown, depth of the epilimnion will increase. Volume of the epilimnion may also increase due to a greater accumulation of warm water, resulting from sub-surface drawdown.

The beneficial effect on productivity of an increase in nutrient supply from the leaching of flooded land may be off-set to a certain extent by draw-down and increased epilimnion depth. The epilimnion may become too deep to allow optimum utilization of both radiant energy and nutrients in the hypolimnion (deep water layer).

In summary, limnological conditions in Duncan Lake may be altered in a variety of ways. Initial increase in productivity may result from introduction of nutrients from inundated soils and increased clarity (with higher photosynthetic activity) caused by more efficient settling of silt from Upper Duncan River in the long reservoir basin. Reduction in productivity may result from draw-off of richer bottom water and smothering of bottom fauna as well as serious reduction in littoral (shallow water) populations of bottom organisms. The complex of factors affecting total productivity of Duncan reservoir is difficult to assess.

Impoundment of water will affect two populations of <u>bottom fauna</u>. The first will be the population existing in Duncan Lake before impoundment; the second will be the newly established population in the area which will be periodically inundated by the reservoir. The former will be adversely affected by the greatly increased depth at which bottom organisms will be placed for part of the year. Unless the organisms are able to move to shallower water they likely will not survive this inundation. Also, the increase in sedimentation in Duncan Lake may further reduce presently existing populations of bottom fauna in the lake by smothering. The latter populations will be affected by seasonal fluctuations in water level; alternate flooding and dehydration will leave the periphery of the lake relatively barren.

In 1963, bottom dredge samples were taken to determine the kinds of bottom fauna present in Duncan Lake. An Ekman dredge, capable of sampling 81 square inches of bottom was used to obtain 80 bottom dredgings, 58 of which were from less than 50 feet water depth. In all, 928 organisms were obtained, or 11.8 organisms per dredging. The following table shows the kinds of organisms obtained.

TABLE VI - Numbers and kinds of bottom organisms taken by bottom dredging, summer, 1963.

Order Diptera (insect larvae)	
F. Ceratopogonidae and F. Chironomidae -	889
Others	
Phylum Mollusca (clams, snails)	
Class Pelecypoda	
F. Sphaeaiidae	25
F. Unionidae	3

Class Gastropoda	
F. Planorbidae	3
F. Physidae	1
Phylum Annelida (leeches)	
Hirudinae	7
	928

If Duncan Lake is divided into five areas--south end, south bay, mid lake, north bay, north end (see Figure 15) and the number of organisms per dredging is considered in each division, an interesting comparison can be made:

TABLE VII Capture areas and depths of organisms obtained by bottom dredging, Duncan Lake, summer, 1963.

	Less than 50 ft. water depth 58 dredgings	Greater than 50 ft. water depth 22 dredgings
South end	6.7	2.1
South bay	24.0	9.7
Mid lake	6.2	2.3
North bay	6.1	2.3
North end	51.6	42.0

The mean number of organisms per dreding was almost the same in both depth groups--12.4 for those under 50 feet in depth and 10.5 for those over 50 feet in depth. This unusual circumstance was due to the large number of organisms found in the North end at all depths. This large number may have been due to a large influx or organisms from the Upper Duncan River, flowing into Duncan Lake at this point. If these particular dredgings are deleted, the average number of organisms per dredging over 50 feet in depth would have been 3 and under 50 feet depth, 9.7.

Northcote and Larkin (1956) consider bottom fauna to be sparse when the number of organisms per 81 square inches is 10 or less, moderate when between 11 and 25 and abundant when greater than 25. By this index, bottom fauna in Duncan Lake is sparse to moderate.

Figure 15 relates bottom fauna to turbidity (measured with a standard Secchi disc). No positive correlation exists, except in South Bay where bottom fauna is relatively abundant and water is clearest. Because most of the filled reservoir will be steep sided, erosion of the banks will be rapid. Wave action against the banks will break up existing vegetation and humus and will expose bare rock. Water level fluctuations will produce a wide band denuded of vegetation and supporting little bottom fauna around the reservoir.

In summary, there will be a decrease in number of bottom dwelling organisms due to reduction of suitable habitat and a reduction in numbers of species due to the increased specialization required to survive under the new environmental extremes.

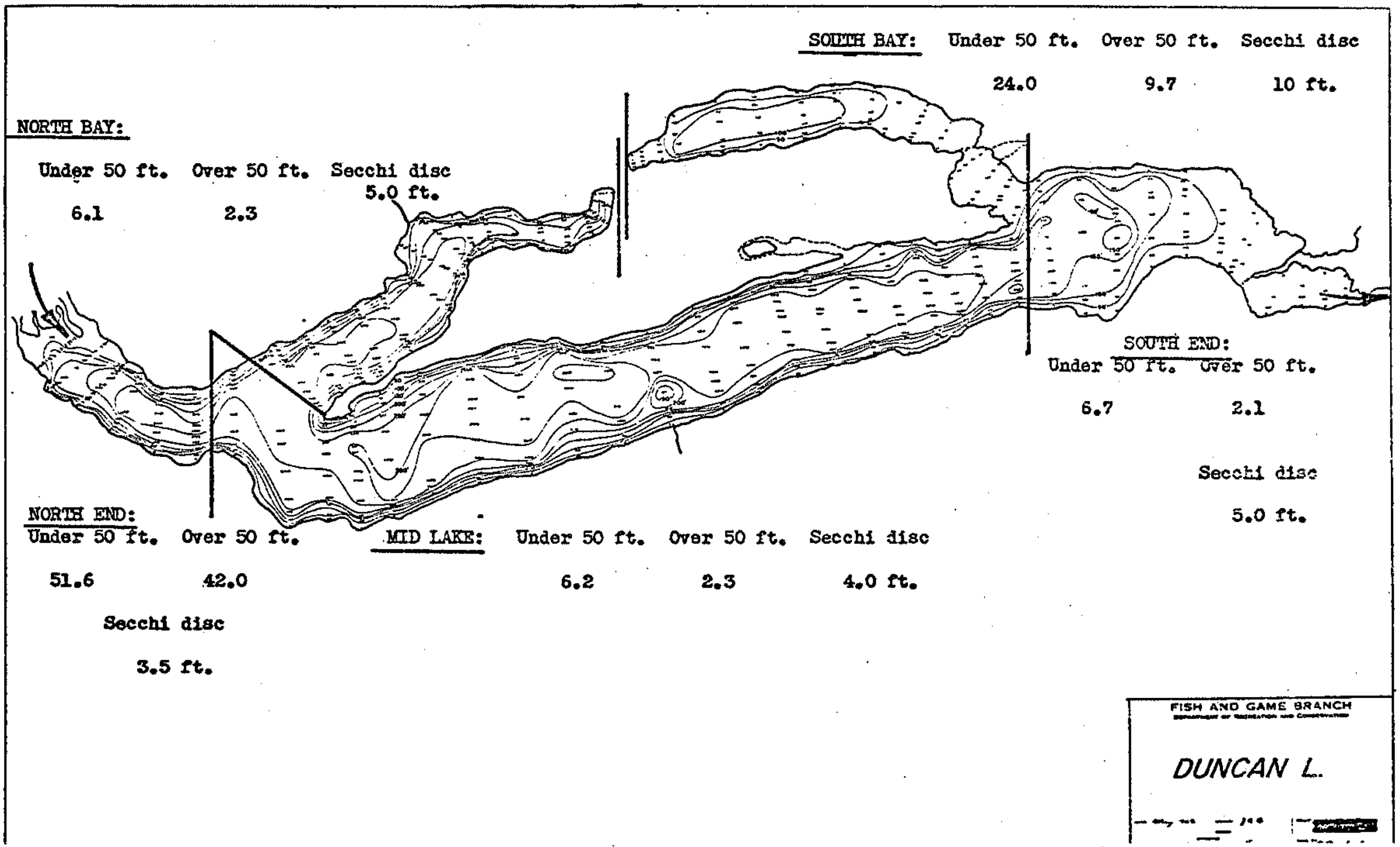


FIGURE 15. Duncan Lake bottom fauna distribution (number of organisms/dredging).

Immediately after flooding of present on-shore areas terrestrial organisms will become available to the fish as food. Terrestrial insects and worms will be in great abundance for the first few years, but being terrestrial, the supply will not be replenished in an aquatic habitat and will eventually become exhausted.

During the first few years of impoundment, some species of forage fish will flourish as a result of increased food supply, and they will thus become more available to other fish as a source of food. For example, many cyprinid species (minnows) will utilize the increased plankton production and produce an abundant food supply for predator fish such as rainbow trout, Dolly Varden char and squawfish.

Lower Duncan River

Production of bottom fauna in Lower Duncan River should increase if water clarity increases. However, it is probable that a marked reduction in temperature will occur below the dam, thus offsetting beneficial effects of increased light penetration and lack of silt. The concurrent effects of these factors is difficult to predict. Sudden water releases and level fluctuations may seriously reduce bottom fauna populations in tail-water areas.

Effects on Sport Fish

Dam construction will affect fish populations both within Duncan Lake and River and in Kootenay Lake. Fish in Duncan Lake will be affected at all stages of their life cycle; Kootenay Lake rainbow trout, Dolly Varden char and kokanee will be affected during growth periods in the lake and during spawning and incubation in the Lardeau-Duncan river system.

Duncan Lake

Growth rate changes in fish populations in Duncan Lake may be brought about by changes in feeding habits of the fish. As mentioned previously, any initial period of increased productivity lasts for a short time. Its duration depends on lake topography, rate at which minerals and nutrients are leached from the soil and extent of water level fluctuations. Duncan reservoir, with its steep, easily eroded shores and extreme water level fluctuation, will have a short period of improved feeding conditions. Any increased growth of sport fish (particularly rainbow trout) will be terminated within a few years of initial impoundment. Coarse fish such as suckers, chub and shiners will also show initial growth increases.

Earthworms are the chief terrestrial food utilized. They are the principle food found in trout stomachs in many new reservoirs. Campbell (1956) found an increase in size in older fish only. Trout in their first and second years showed no initial size increase. Campbell postulated that the large size of terrestrial organisms precluded their use by smaller fish as food items. Utilization of larger terrestrial food forms with a comparatively small output of energy should increase efficiency of conversion of fish food organisms to fish flesh.

Dolly Varden may initially utilize the abundant terrestrial organisms, but this species of fish is diversified in its feeding habits, often feeding on fish and plankton as well as on bottom fauna. These fish may better adapt themselves to reservoir conditions after the increased supply of terrestrial organisms is reduced. When bottom fauna is reduced those fish dependent on bottom organisms must seek a new source of food.

Changed conditions within Duncan reservoir and its tributary streams may affect the numbers of each species of fish in the reservoir. Game fish such as rainbow trout, Dolly Varden char and mountain whitefish probably will decline in numbers due to loss of food and restriction of spawning grounds. Non-game fish species, such as squawfish, suckers, peamouth chub, dace and sculpins may increase in numbers in the reservoir, because of their greater adaptability to changed conditions. These species are more diversified in their feeding habits, and they probably will have less competition for food from sport fish.

Lower Duncan River

Rainbow trout, Dolly Varden char and mountain whitefish were observed in Duncan River downstream of the dam-site. Following construction of the dam, all species in the river below the dam will be subjected to colder water temperatures than at present during the period April 15 to November 1. On the other hand, winter temperatures will be higher favouring increased production of fish food and fish. The net effect of these temperature changes cannot at present be predicted for resident fish in Lower Duncan River.

Kootenay Lake

Operation of Duncan reservoir will probably have seriously adverse effects on fish which are of great importance to the Kootenay Lake sport fishery. Kokanee salmon, which utilize Lower Duncan River for spawning will be eliminated from Duncan River upstream from the confluence of Lardeau and Duncan Rivers. Rainbow trout and Dolly Varden char will also be eliminated from the same area, but may utilize downstream areas to some extent if siltation is reduced.

Altered flows in Lower Duncan River in May through July can have serious effects on homing and migratory behaviour on rainbow trout in May, on Dolly Varden in July and on kokanees in September and October.

Rainbow trout destined to spawn at Gerrard, on the upper Lardeau River, migrate from Kootenay Lake from approximately May 1 to May 20 of each year. Reduced flows in Duncan River below its confluence with Lardeau River, together with colder water from Duncan reservoir may delay the rainbow trout migration to such an extent as to seriously reduce spawning success on the upper Lardeau. Delay of spawning for rainbow trout can result in increased egg and fry mortality if eggs are deposited at later than normal dates in the Lardeau River. Egg deposition, fry emergence and fry migration are keyed to water flows and temperature of river water; hence any change in timing of the spawning migration may result in a changed chronology for progeny. Since reproductive behaviour for fish populations has been a result of evolutionary selection over a very long time, changed migration, spawning and hatching times will result in reduction of recruitment to the trout population.

Dolly Varden char migrate into the Duncan-Lardeau River system from Kootenay Lake principally in July. These fish often can be observed spawning in smaller tributaries of the Duncan and Lardeau River in August and (occasionally) September. Specimens of large fish (in excess of 30 inches in length, 10 pounds in weight) have been obtained in summer from tributary streams but not from Duncan or Lardeau River. Spawned-out Dolly Varden char have been passed downstream through fish traps on Meadow Creek early in September. Drastically reduced flows and changed water temperatures in Lower Duncan River will probably delay Dolly Varden migration in the same manner as for rainbow trout. In addition, the fairly extensive Dolly Varden spawning habitat in the area of the Duncan dam will be eliminated, and any fish which might traditionally spawn in the Upper Duncan River after migrating through Duncan Lake will be blocked from ascent of the river.

Kokanee appear in large numbers off the mouth of Duncan River in Kootenay Lake in the last week of August and the first week of September. Discharge from the Duncan dam at this time of year probably will approximate 6,000 c.f.s. Sufficient flow will exist in the Lower Duncan River to attract kokanee, but the temperature of the water discharged from the reservoir will probably be in the range of 40° F. to 45° F., which is 15 to 25 degrees colder than water presently flowing out of Duncan Lake in August and September. Homing of fishes (returning to their natal streams) is largely dependent on physical and chemical characteristics of the stream water in which they are hatched. Alteration of the chemical character of Duncan River water below Duncan dam probably will be slight, although it is unpredictable at present. Temperature reduction (see previous page), however, will be extremely large, and may prove a most serious threat to kokanee migratory behaviour and reproductive success.

Data on the thermal structure of the north arm of Kootenay Lake are available from independent research on the lake, and suggest that at present, Duncan River maintains its identity as a sub-surface current after entering Kootenay Lake (Larkin, 1951). Bathythermograph records of water temperatures indicate that Duncan River, after entering Kootenay Lake, submerges and flows along the west side of the lake toward the south, and is identifiable as a flowing water mass by its thermal structure. Homing migrant spawners may orient to this water mass when moving northward toward the mouth of Duncan River. Reduction of temperature in Duncan River will cause the river flow in Kootenay Lake to dive to a deeper level in the lake, and will most probably affect migratory behaviour of all species orienting to it.

Information on movement of rainbow trout, Dolly Varden char and kokanee salmon in Kootenay Lake is lacking at present. In addition, nothing is known of the direct effects of Duncan River water on the sport fishing in Kootenay Lake. A general prediction can be made that ecological conditions in the north arm of Kootenay Lake may be profoundly changed by dam operation. Until information from Kootenay Lake can be integrated with data collected in Duncan and Lardeau Rivers, the course of events with respect to migratory fish cannot be predicted with any degree of confidence.

Further studies are in progress on migratory habits of the three most important species of salmonids ascending from Kootenay Lake into the Duncan-Lardeau River system. These fish (rainbow trout, Dolly Varden char and kokanee salmon) constitute the populations upon which the Kootenay Lake fishery is based. Rainbow trout are the most highly prized; Dolly Varden char, which attain larger size, are also avidly sought; kokanee (which are also important to anglers) provide the main source of food for both rainbow and Dolly Varden, after individuals of these two species reach a size in excess of 18 inches in length.

Effects on Wildlife

Waterfowl and aquatic fur bearer habitat will be completely removed from the Duncan drainage. Migration habitat will be removed for about 50,000 ducks, 5,000 geese, 1,000 swans and other waterfowl and wetland species. At present little basis exists for an accurate estimate of beaver and muskrat resources of the Duncan drainage, but about 1,000 beaver and 2,000 muskrat may be displaced.

Whitetail deer in the Duncan drainage will be displaced; about 400 are involved. Mule deer, elk and caribou will be reduced in numbers through loss of range, drowning and the barrier effect of the reservoir. The extent of these populations is not accurately known at this time, but establishment of the reservoir will probably displace about 200 individuals of these species. Black bear will be reduced in numbers and the few grizzly bear that periodically occupy the reservoir area will probably be affected. There are presently about 25 black bear and 5 grizzly bear in the area. Moose evidently occupy tributary valleys but do not winter in numbers in the mainstem Duncan valley; therefore the reservoir will probably have little effect on this species, except possibly during periodic severe winters which force moose to lower elevations. Goat populations in the Duncan drainage should not be affected by the reservoir.

Forest habitat flooded will remove unknown populations of squirrel, marten, weasel, fisher and grouse.

Other wildlife species affected by the loss of wetland habitat include bald eagle, osprey, coot, blue heron, grebes, snipe, plover and many other small birds and mammals.

Access to game populations in tributary valleys of the Duncan system may be affected by the reservoir, depending on many unknown aspects of the project development such as land use and tenure of adjacent areas and construction of access roads.

S U M M A R Y

1. The study described by this report was made to evaluate changes in fish and wildlife populations and recreation attributed to installation and operation of Duncan Lake dam.
2. The lakes, streams, and adjacent lands were studied for their suitability as fish and wildlife habitats. Particular emphasis was placed on migratory spawning fish from Kootenay Lake.
3. The Upper Duncan drainage area was found to support a relatively small and unimportant sport fishery. Of

considerable importance, however, are the spawning grounds for Kootenay Lake rainbow trout, Dolly Varden char, and kokanee in the Duncan-Lardeau system. Resident fish will be affected by the dam through loss of spawning grounds and loss of food. The Kootenay Lake fish (rainbow trout, Dolly Varden char and kokanee salmon) which migrate into the Duncan system will be affected by loss of spawning grounds, loss of food, and a change in the ecology of the North end of Kootenay Lake.

4. The Duncan drainage area supports a large number of game animals, waterfowl, and fur bearers which will be lost as a result of flooding of habitat. These animals are both resident and migratory. They are at present only lightly exploited due to lack of access to the area.

5. The present recreational use of the area is very limited due to the relative inaccessability of the area, cold water in Duncan Lake and lack of beaches on Duncan Lake. The demand for the area as a recreational outlet after the reservoir is filled could be quite high because of increased overall demand for such outlets, scenic value of the dam and warm reservoir water.

6. The evaluation of the changes to fish, wildlife, and recreation now presented cannot be considered complete.

Examination of the Duncan drainage area and its fish and wildlife populations provided only the most elementary inventory of the fish and wildlife resources.

7. Specific recommendations concerning losses of fish and wildlife on the Duncan-Lardeau system cannot be made until further studies are carried out. Research work presently underway on Kootenay Lake, independent of this study and the kokanee enumeration study of 1964 (Bull, 1964) will bear heavily on final assessment of the effects of Duncan dam on fish populations. Further game species investigations will provide the basis for assessing effects on terrestrial wildlife (including fur bearers) and waterfowl populations.

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Management publications of the British Columbia Fish and Wildlife Branch contain material primarily of regional interest. They are issued at irregular intervals and supplement the publications by staff biologists in standard scientific journals.

The following publications have been issued to date:—

P. A. Larkin, G. C. Anderson, W. A. Clemens, and D. C. G. Mackay (1950): The production of Kamloops trout (*Salmo gairdnerii kamloops,* Jordan) in Paul Lake, British Columbia. 37 pp. (Rubber-stamped " Scientific Publications of the British Columbia Game Department Number One.")

Management Publication No. 1 (P. A. Larkin, 1951): The effects on fisheries of proposed West Kootenay water-storage project at Trout Lake. 25 pp.

Management Publication No. 2 (R. G. McMynn and P. A. Larkin, 1953): The effects on fisheries of present and future water utilization in the Campbell River drainage area. 61 pp.

Management Publication No. 3 (S. B. Smith, 1955): Summary of autumn sport-fishing records, 1949–54, from the B.C. Game Commission checking-station at Cache Creek, B.C. 11 pp.

Management Publication No. 4 (S. B. Smith, 1955): Distribution and Economics of the British Columbia sport fishery, 1954. 22 pp.

Management Publication No. 5 (I. L. Withler, 1965): A limnological survey of Atlin and southern Tagish lakes, with special reference to their proposed use as hydro-electric storage reservoirs. 36 pp.

Management Publication No. 6 (T. G. Northcote, 1957): Common diseases and parasites of fresh-water fishes in British Columbia. 25 pp.

Management Publication No. 7 (John W. Cartwright): Investigation of the rainbow trout of Kootenay Lake, British Columbia, with special reference to the Lardeau River. 46 pp.

Management Publication No. 8 (G. R. Peterson and I. L. Withler): Effects on fish and game species of development of Duncan dam for hydro-electric purposes. 72 pp.

Management Publication No. 9 (G. R. Peterson and I. L. Withler): Effects on fish and game species of development of Arrow Lakes dam for hydro-electric purposes. 43 pp.

Management Publication No. 10 (G. R. Peterson and I. L. Withler): Effects on fish and game species of development of Mica Creek Dam for hydro-electric purposes. 67 pp.