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Atlantic-Salmon (*Salmo salar* L.) Development in the Tetagouche River, New Brunswick, A Feasibility Study

by
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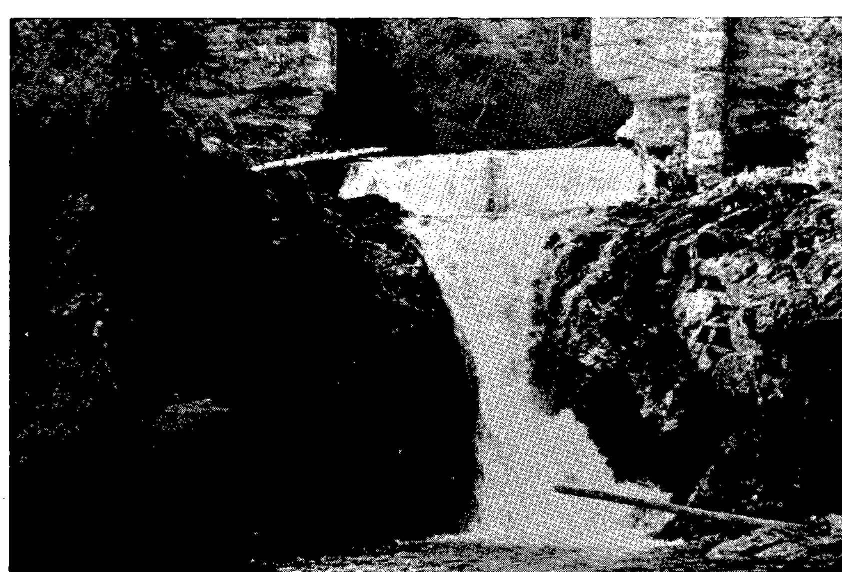

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ATLANTIC SALMON (*SALMO SALAR* L.) DEVELOPMENT IN THE TETAGOUCHE RIVER, NEW BRUNSWICK

A FEASIBILITY STUDY

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MARCH, 1977

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FRESHWATER AND ANADROMOUS DIVISION
RESOURCE BRANCH
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DEPARTMENT OF FISHERIES AND THE ENVIRONMENT

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CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

The Atlantic salmon run of the Tetagouche River, near Bathurst, New Brunswick, has never utilized the area above a 10.7-m natural falls located 14.5 km from salt water. Approximately 74% of the stream area lies above this falls.

The Tetagouche River flows through an area rich in heavy metals, particularly copper, zinc and lead. Although no base-metal mining operations have yet been established in the watershed, at times the natural runoff waters contain relatively high concentrations of base-metal ions, particularly copper.

This report gives the results of: (1) a physical and biological survey to determine the Atlantic salmon production potential of the river; (2) field and laboratory bioassays conducted to determine whether natural copper concentrations were lethal to Atlantic salmon, and whether this species has acclimated to high concentrations of heavy metals; and (3) a fish passage alternatives study for upstream migrants at Tetagouche Falls.

DESCRIPTION OF TETAGOUCHE RIVER

The Tetagouche River, located in northeastern New Brunswick (Fig. 1), has a meander length of 67.2 km and drains 363 km^2 of

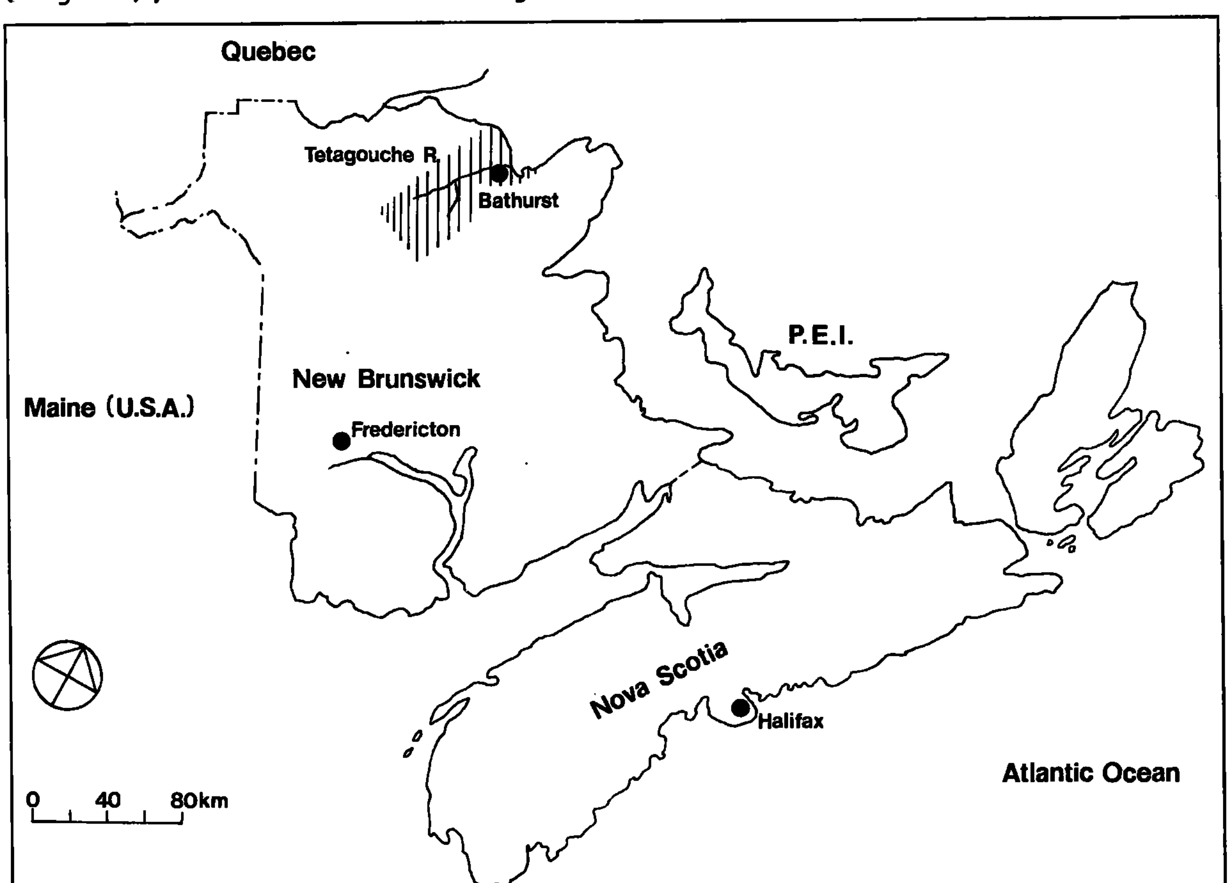

FIG. 1. Location of Tetagouche River, Bathurst, New Brunswick.

forested country. From its origins in the woodlands of eastern Restigouche County, it flows due east through Gloucester County and empties into Bathurst Harbour near the town of Bathurst. The average drainage-basin elevation is 290 m. The Tetagouche system includes only three lakes, with a combined area of 123 hectares. Upper and Middle Tetagouche lakes are located near the headwaters, and Lower Tetagouche Lake is located 42 km from salt water (Fig. 2). The river has one major tributary, the South Tetagouche River. The average stream gradient of the main stem is 7.5 m/km. The steepest portions are located between Lower Tetagouche Lake and the confluence of the South Tetagouche tributary, and below the Tetagouche Falls for approximately 3.2 km.

For a good part of its course, the Tetagouche River flows in a deep forested valley; from Tetagouche Falls, for several kilometers, the steepness of the banks make access practically impossible.

The only complete obstruction to upstream migration of Atlantic salmon in the entire system is the 10.7-m Tetagouche Falls, situated 14.5 km from the river mouth. The crest of the falls has been raised 2.4 m, and narrowed from 18.2 to 10.3 m by the remnants of a concrete hydroelectric dam (Fig. 3). The dam is no longer utilized, but a substantial structure remains. The provincial Department of Natural Resources, Parks Branch, has begun development of this site as a picnic ground. The remains of the old power development—which consist of a partially breached dam, penstock renmants, draft tube and turbine housing—do not constitute a historical attraction sufficiently valuable to prevail over the provision of fish passage.

A partial obstruction exists at "Squirrel Jump", approximately 4.8 km below Tetagouche Falls. It consists of a 2.4-m falls onto a flat rock ledge (no plunge basin), which can obstruct migrating salmon—particularly at the extreme ranges of river discharge.

Twenty-six years of data recorded near the mouth of the river revealed daily minimum and maximum discharges of 0.42 and 152.3 m^3/sec, respectively. The mean annual discharge over this period was 7.9 m^3/sec.

BIOLOGICAL SURVEY

A biological survey of the Tetagouche River above Tetagouche Falls was conducted in 1970. The main purpose was to estimate the extent of salmon rearing and spawning areas that would be made accessible by the provision of fish passage facilities at Tetagouche Falls, and the resulting increase in production potential. A 13.6-km section of river below the gorge, extending to salt water, was surveyed in 1972.

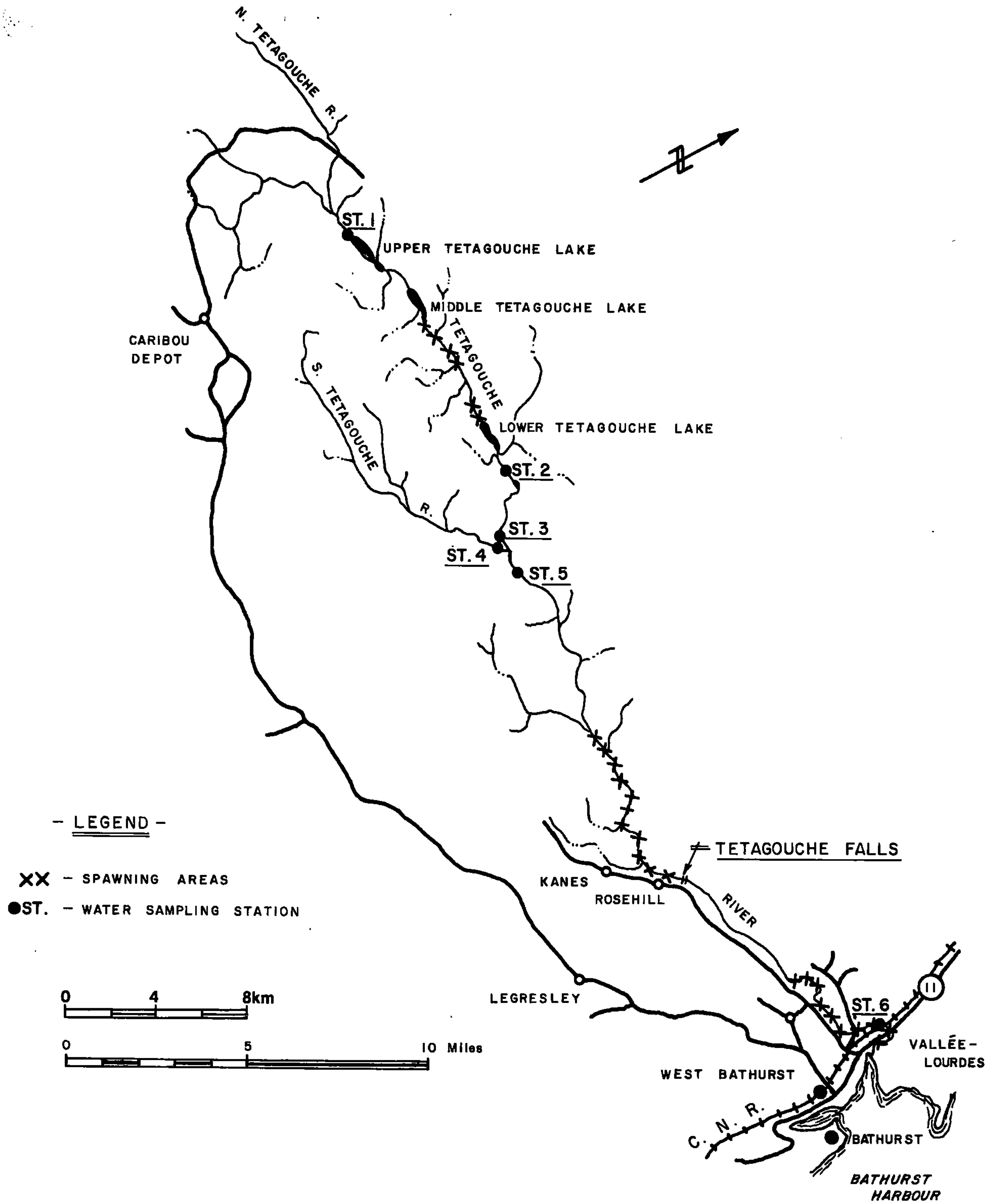

FIG. 2. Map of Tetagouche River, New Brunswick, showing the distribution of present and potential Atlantic salmon spawning areas and the locations of water sampling stations.

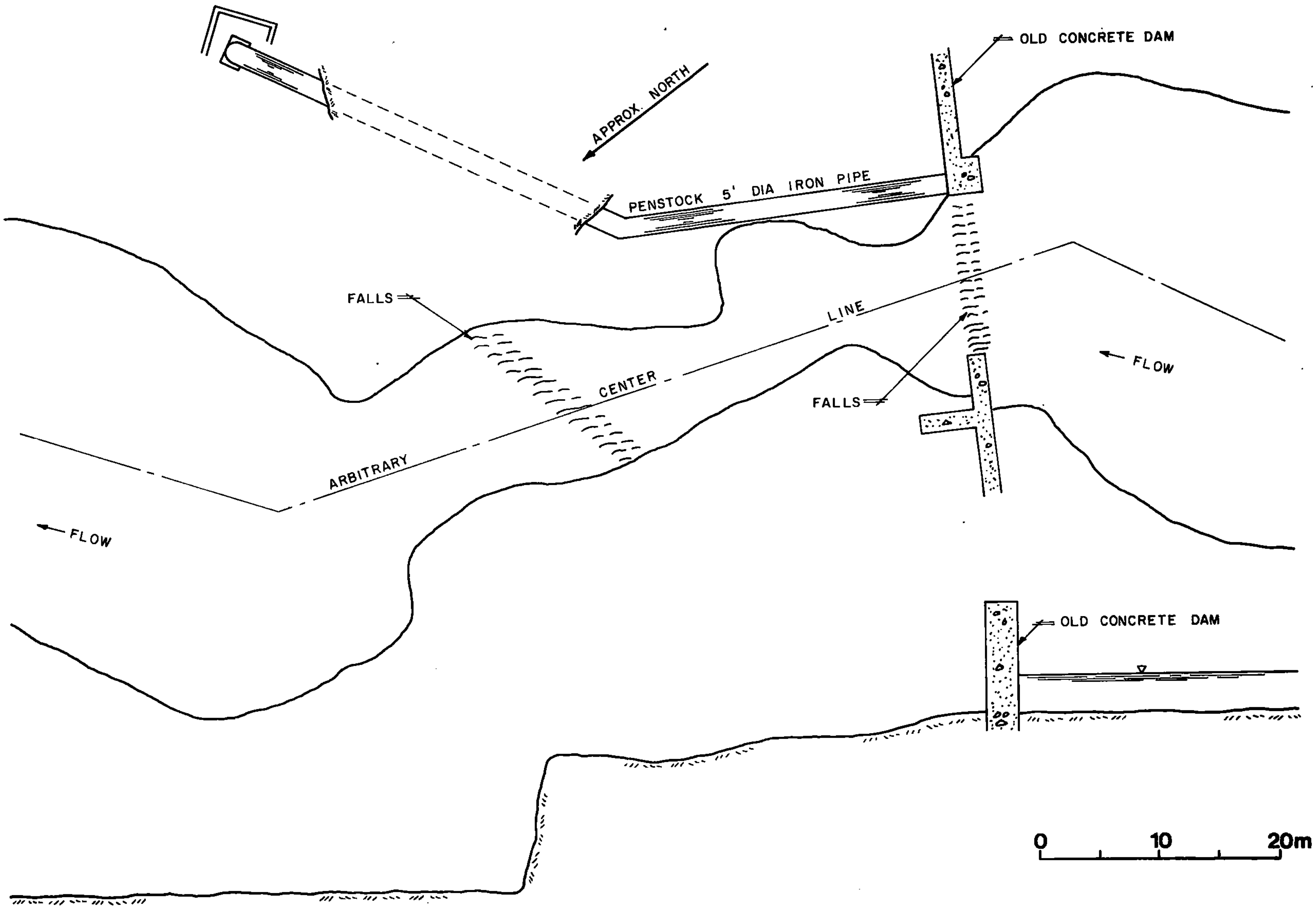

FIG. 3. Site plan and profile of Tetagouche Falls, showing the remnants of the power development.

Salmon Habitat

Seventy-four percent of the potential salmon habitat in Tetagouche River is found above Tetagouche Falls, in the main stem of the river and the tributaries. The bulk of the spawning grounds for that area is found from the Tetagouche Falls at Kilometer 13.6 to Kilometer 24.0. The river bottom in that section consists of medium to coarse gravel, with some large stones. The remainder of the spawning grounds are found in the lower 6.4 km of the river, below the falls, and scattered in the tributaries. The lower Tetagouche has approximately 2 large pools per kilometer. These pools vary in depth from 1 to 6 m, and in area from 25 to 1,340 m^2.

Rearing grounds are found throughout the main stem, including the area between the Tetagouche lakes, and in the tributaries—particularly the South Tetagouche River.

Potential Salmon Production

The estimate of potential salmon production in the Tetagouche River is based on the rates of survival given by Elson (1957). Assuming a production level of 1 or 2 smolts per 100 m^2 and an average sea survival of 8%, the Tetagouche River could produce from 11,000 to 22,000 smolts, with resulting adult runs ranging from 880 to 1,760 fish. At least 74% of these fish would be produced above Tetagouche Falls.

Atlantic salmon presently frequent the 14.5-km stretch of river from the mouth to Tetagouche Falls. The upper 9.1 km of this section flow through a ravine, 25-70 m deep. In this inaccessible section, the river bottom is largely bedrock and, therefore, is not ideally suited to juvenile salmon rearing. The lower 5.4-km section is accessible by roads at several points, and is considered to be an excellent rearing and spawning area. Electrofishing was used to determine the species of fish present, but no quantitative information was obtained on juvenile salmon population density. The area is, however, believed sparsely populated by juvenile salmon.

Based on habitat distribution (Table 1) and on previously mentioned survival rates, the adult runs to the lower Tetagouche River should range from 240 to 480 fish. Angling records for 23 years, 1953-75 (Table 2), indicate a gradual decrease in the catch to 1972, which is in keeping with the general trend in the salmon streams of northeast New Brunswick (Ducharme 1972). The data also show an increase for the years 1973-75, which is probably related to the ban on the commercial fishery imposed in 1972. Assuming a 25% angling exploitation, the catch data suggest that actual production of the lower river during the period 1953-57 approximated the estimated potential, but that present levels are much lower.

The adult run takes place from July to September. The grilse:salmon ratio from 1968 to 1971 was 10:1.

TABLE 1. Salmon habitat distribution in the Tetagouche River, New Brunswick.

Stream section	Area (m^2) Spawning	Area (m^2) Rearing	Salmon habitat—spawning & rearing (% of total stream area)
Main Tetagouche, below falls			
Lower (0-14 km)[1]	143,800	155,400	26
Main Tetagouche, above falls			
Upper (40-56 km)	Sparse	101,200	
Middle (14-40 km)	140,800	354,933	54
Tributaries			
South Tetagouche (13 km)	Sparse	140,000	
North Tetagouche (5 km)	"	52,800	
West Tetagouche (3 km)	"	35,200	20
Totals	284,600	840,333	100

[1]Area presently populated by Atlantic salmon.

TABLE 2. Angling catch and effort data for Tetagouche River, New Brunswick.

Years	Average number fish angled annually	Average number rod-days/fish
1953-57	64.8	3.5
1958-62	24.8	5.5
1963-67	46.0	1.8
1968-72	29.4	5.0
1973-75	41.6	11.5

WATER QUALITY

As mentioned previously in this report, the Tetagouche River remains untouched by mining pollution. Analysis of routine water samples in 1970 revealed a natural occurrence of high heavy-metal concentrations in the month of August (Table 3). These

TABLE 3. Results of water-sample analyses from Tetagouche River, New Brunswick, August 9-17, 1970.

Sampling stations[1]	Location	Heavy metal concentrations (ppb)[2] Copper		Zinc		Lead		Total hardness (ppm)
1	Above Upper Tetagouche Lake	100	(170)	20	(1,700)	7	(n.a.)	91.3
2	Below Lower Tetagouche Lake	20	(110)	20	(1,200)	20	(2,100)	51.0
3	Main river, above South Tetagouche confluence	20	(120)	0	(1,300)	0	(n.a.)	62.6
4	South Tetagouche River, near mouth	50	(56)	120	(750)	12	(980)	23.2
5	Main river, below South Tetagouche confluence	60	(120)	20	(1,300)	12	(n.a.)	62.2

[1]Correspond to numbers on map.

[2]Figures in parentheses indicate incipient lethal levels for rainbow trout at the given hardness (summer water temperature and pH near neutral) (Lloyd and Herbert 1962).

relatively high concentrations persisted during the month of December, after temperatures dropped below freezing (Table 4).

TABLE 4. Results of summer and winter water analyses from Tetagouche River (Station #6), New Brunswick, 1970.

Date	Heavy metal concentration (ppb) Copper	Zinc	Lead	Total hardness (ppm)	pH	Water depth (m)
17 Aug	20	17	0	56.4	8	0.8
11 Dec	70	20	0	60.0	7	0.3
19 Dec	20	20	0	58.4	8	0.5
22 Dec	50	100	0	63.0	7	0.5

Concern was felt that lethal levels of a single toxic element (Cu) or combinations of toxic elements (Cu, Zn, Pb) might occasionally be reached under natural conditions. This could result in significant mortalities to various year-classes of resident juvenile salmon and cause an avoidance reaction in adult migrants. A series of field and laboratory investigations was initiated to determine the effect of Tetagouche water on a foreign stock of juvenile salmon, and whether Tetagouche River salmon had become acclimated to heavy metals.

Since the natural occurrence of heavy-metal concentrations in Tetagouche River does not appear correlated with times of high runoff, and acute toxicity of metal ions (except zinc) increases with increasing temperature (Sprague 1964), it would appear that the critical time of year for fish life is during the dry months of July and August.

Several hypotheses have been developed regarding the heavy-metal concentrations observed during the 1970 survey and their subsequent effects on juvenile salmon.

1. The toxicity "slugs" of high concentration (70-100 ppb Cu) are rare or very localized, and never large enough to cause serious damage to one or more year-classes of juvenile salmon.

2. The measured concentrations of total copper and zinc do not reach lethal limits because of the presence of chemical compounds (such as humic acids), which bind the toxic-metal ions into organic complexes and reduce toxicity.

3. Juvenile salmon have become acclimated to high copper and zinc concentrations.

Hypothesis 1 is difficult to verify because of the extensive water-quality monitoring it would require. Attempts were made to verify Hypotheses 2 and 3 by means of static laboratory bioassays and field bioassays. These experiments were conducted from 1971 to 1972.

Static Bioassays (1971)

Under the direction of Mr. Ray Côté (1971), a series of bioassays was conducted at the Bedford Toxicity Laboratory. The three main purposes of the investigation were as follows:

1. To determine the effect of Tetagouche water and its high heavy-metal content on a foreign stock of salmon from a low-mineral-content river.

2. To determine whether Tetagouche salmon are acclimated to the high concentrations of copper sometimes found in their river of origin, or whether the copper present is simply in a less toxic form.

3. To determine the upper limits of tolerance, should Tetagouche fish show an acclimation ability to high copper concentration.

Wild juvenile salmon from the Cains River, New Brunswick, and the Tetagouche River were used as experimental fish. These fish were captured by means of an electric shocker and transported to the Bedford Toxicity Laboratory in a fish tank truck. Temperature, pH and dissolved oxygen were maintained at a constant level during tests. The tests were made at two hardness levels (31-36 ppm and 77-78 ppm); and, for each level, four concentrations of Cu were tested (25, 50, 100 and 200 ppb). The results showed that the 96-hr median tolerance limit (TLM) for the Cains River and Tetagouche River fish in their respective river waters and Cains River fish in Tetagouche water were 62, 65 and 66 ppb Cu respectively. Doubling the hardness appeared to have no effect on fish survival.

Two avoidance tests suggested that, when given a choice, Cains River fish prefer Cains River water to Tetagouche River water and Tetagouche River water to laboratory dechlorinated water.

Harmful effect of Tetagouche water and its high heavy-metal content on Cains River fish was not demonstrated conclusively. The possibility of Tetagouche salmon being acclimated to a higher concentration of copper is remote, since the 96-hr TLM for Cains River salmon in Tetagouche water is essentially the same as for Tetagouche salmon in Tetagouche water.

Similar tests were conducted in 1963 at St. Andrews, New Brunswick, on juvenile salmon from the Exploits River, Newfoundland, (Sprague, unpublished)[1]. The purpose was to determine if, due to longstanding base-metal pollution in that river, juvenile salmon might have developed some resistance to copper and zinc. The mines causing the pollution had been functioning for a long time (ten generations of salmon). The St. Andrews test results showed that the Newfoundland salmon parr had the same resistance to copper as did wild populations from New Brunswick rivers or hatchery stocks.

Field Bioassays (1971 and 1972)

The objective of the field bioassays was to determine the effects, if any, of natural occurrences of heavy metals in the Tetagouche River on wild juvenile salmon from the Cains River, New Brunswick, and on hatchery-reared yearling salmon.

In 1971, 20 salmon parr were collected from the Cains River and transported to Tetagouche River to be held in two cages set

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[1]Contained in circulars from St. Andrews Biological Station, New Brunswick.

near Vallée Lourdes (Fig. 2). Only three parr from Tetagouche River were available as a control group. The bioassay test began on August 13 and was abruptly terminated on August 19, due to vandalism. No mortalities were recorded during that period. Temperatures ranged from 15° to 18°C, dissolved oxygen levels from 9 to 10 ppm and pH was steady at 8.0. On August 17, the heavy-metal content was 20 ppb Cu and 19 ppb Zn, and total hardness was 62.6 ppm.

In 1972, 200-hr bioassays were conducted at two stations at medium (July 12-21) and low (Aug 10-19) water levels. Station 1 was located below middle Tetagouche Lake, 50 yd downstream from a road bridge. Station 2 was located at the railroad bridge in Vallée Lourdes (Fig. 2). The experimental fish were hatchery-reared Atlantic salmon yearlings, raised at Charlo Hatchery in water free of copper and with only 0.001 ppb of zinc. Maximum and minimum water temperatures, water levels, dissolved oxygen and pH were measured daily. One-liter water samples were taken on each of the first four days (96 hr) for all experiments. The water samples were later analysed at the Bedford Toxicity Laboratory.

No mortality was observed in the caged fish for the entire duration of the experiments. The measured heavy-metal concentrations (first 96 hr) remained comparatively low at both stations (Table 5).

The volume and duration of the "slugs" of high concentrations of heavy metals observed in 1970 were not determined. Although the presence of heavy metals was revealed in all subsequent water analyses, the concentrations measured were much lower, suggesting that high concentration levels are isolated in occurrence. A young salmon would have to spend approximately 48 hr in water having a copper concentration of 70-100 ppb before death ensued (Côté 1971). Lloyd and Herbert (1962) found that toxicity of heavy metals to rainbow trout *(Salmo gairdneri)* was inversely related to the water hardness (Tetagouche hardness ranged from 52 to 74 ppm). They also determined that mixtures of poisons (Cu and Zn) have cumulative effects on the survival of salmonids. Sprague (1964), found the lethal level of copper and zinc to juvenile Atlantic salmon at a total water hardness of 20 ppm and 17°C to be 48 ppb and 600 ppb, respectively.

There is a self-perpetuating salmon population in the Tetagouche River. The declining adult runs, as reflected by declining angling catch, is believed related to causes other than pollution in the home stream. Atlantic salmon's freshwater cohabiting species, such as the blacknose dace *(Rhinichthys atratulus)* and common white sucker *(Catostomus commersoni)*, are found throughout the river system. The examination of 15 stream-bottom-fauna samples, collected with a Surber sampler in riffles at three locations on the river (Aug 1972), indicated average richness. The mayflies (Ephemeroptera), which are more sensitive to heavy metal pollution (Sprague et al. 1965), were well represented, 36% by number, suggesting non-lethal heavy-metal pollution.

TABLE 5. Summary of bioassay test results, Tetagouche River, 1972.

Parameters measured (ranges)	Experiment 1 (12-21 Jul) Station 1	Experiment 1 (12-21 Jul) Station 2	Experiment 2 (10-19 Aug) Station 1	Experiment 2 (10-19 Aug) Station 2
Total exposure time (hours)	209.8	211.3	219.2	220.2
Mortality	nil	nil	nil	nil
Water temperature (°C)	15.0-26.7	15.5-27.8	11.7-20.5	12.8-23.3
Water level variation (ft)	0.6	0.7	0.3	0.4
Discharge (m^3/sec)	2.2-4.1	4.5-10.4	1.0-2.3	2.0-7.0
Heavy metal concentrations[1]				
Cu (ppb)	6-16	3-25	4-5	3-9
Zn (ppb)	14-21	4-13	14-21	5-16
Pb (ppb)	5-8	5-6	5-8	5-12
Dissolved oxygen (ppm)	8-9	8-9	8-9	8-9
pH	7-8	7-8	7-8	7-8
Total water hardness (ppm)	64-67	52-56	67-74	55-60
Average parr length (cm)	10.7	11.0	12.6	13.3

[1]Water sample collected daily for the first four days.

SOURCE OF SEEDING STOCK

Five consecutive years of fish stocking will be required to develop self-perpetuating salmon runs to the upper Tetagouche River. Adult broodstock collection from the lower Tetagouche would undoubtedly be difficult, due to the reduced number of fish presently entering the river and the general lack of access to the river. As an acclimation to heavy-metal concentrations in Tetagouche fish was not confirmed by field and laboratory investigations, the use of Tetagouche stock to develop the upper river does not appear to be crucial. Restigouche River or Miramichi River fish, reared to the fall fry or smolt stage in the nearby Charlo Hatchery, therefore, seem to provide the most practical and economical solution for stock requirements.

The natural smolt output of the Tetagouche River is estimated at 22,500 fish (2 smolts produced per 100 m^2) which should result in adult runs of approximately 1,800 fish (smolt/adult survival of 8%). Taking into consideration the known rates of survival for hatchery-reared smolts and also considering seeding of fall fry as an alternative, the following figures appear realistic if the full production potential of the river is to be reached after five years.

No. rearing units (100 m^2) available	-	11,250
No. fall fry required		
Level 1 (30 fish/100 m^2)	-	337,500
Level 2 (40 fish/100 m^2)	-	450,000
No. hatchery-produced smolts required	-	67,500

Level 1 (30 fish/100 m^2) is the average fry density normally encountered in northeast New Brunswick salmon streams (Lutzac and Peppar, personal communication)[1]. Level 2 (40 fish/100 m^2) includes a factor of 30% overseeding to compensate for mortality losses due to the transfer and adaptation to a new environment. A 300% overseeding factor has been allowed for smolts, since total survival of hatchery-produced fish is seldom higher than 2% (Ritter 1972).

FISH PASSAGE ALTERNATIVES AT TETAGOUCHE FALLS

The remains of the concrete dam on the crest of the Tetagouche Falls raise the height of the obstruction by 2.4 m and narrow the river width to 10.3 m (Fig. 3). The effect of this narrowing would be to increase the fluctuations in the levels to be accommodated at the exit of any proposed fish facilities (Millen 1971, unpublished)[2]. A peak discharge on the Tetagouche of 152.3 m^3/sec occurred (in 26 years of records), which would have raised the water level in the breached section of the dam to 4.3 m. Millen selected 70.7 m^3/sec as the river discharge which should be accommodated at a fishway. For this discharge, the height of the water would be 2.4 m.

Initially, four alternative fish passage schemes were considered, assuming various combinations of type of fish pass and degree of removal of the old dam. It was believed then (1970) that the Parks Branch of the Department of Natural

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[1]Personal discussion with Lutzac, T.G. and Peppar, J.L., biologists, Fisheries and Marine Service, Dept. of Fisheries and the Environment, Halifax, 1976.

[2]Engineering memorandum, files of Resource Development Branch, Dept. of Fisheries and the Environment, Halifax, 1971.

Resources, New Brunswick, would have reservations on the removal (total or partial) of the remains of the concrete dam on the crest of the falls. In August, 1972, verbal assurance was given by Mr. Clayton Allison, District Tourism Officer, Department of Tourism, New Brunswick, that his department would agree to the removal of any parts or all of the concrete dam remains deemed necessary for the economical provision of fish passage. The Fisheries and Marine Service requirement should be the removal of the main part of the dam structure to elevation 42.2 m (left and right wings down to bedrock level). This would reduce the height to be overcome by 2.4 m, give a river width of 22.9 m and a water level variation of only 1 m at the crest during salmon migration periods (1 Jun-30 Nov). Of all the fish passage facilities and locations considered, the best alternative appears to be a vertical-slot fishway located on the true right bank of the site, which would feature approximately the following dimensions and cost:

Pool dimensions	- 2.4 x 3.0 m
Pool depth	- 2.1 m
Width of vertical slot	- 0.3 m
Number of pools	- 46 (includes 3 resting pools)
Estimated cost (1976-77)	- $294,200

To minimize rock excavation and structural support, the fishway design includes two tunnel sections of 21.3 and 15.2 m, respectively (Fig. 4).

Trapping and trucking facilities were not considered, because of the limited access provided by the steep banks of the river for 9.1 km below the Tetagouche Falls. Also, no consideration was given to potential difficulties with downstream migrants, which appear low at this time.

CONCLUSIONS

Based on the results of the study, it is concluded that the development of the Tetagouche River salmon runs is biologically sound and that it is technically feasible. Initially expressed fears that heavy-metal contamination existed in the natural drainage of the river have been removed, as has the possibility of Tetagouche salmon being a very specialized strain (genetically acclimated to heavy metals) and therefore difficult to reproduce. The procurement of stocks in suitable numbers continues to be a problem, but only because of limited rearing space and general shortage of normal broodstock.

SUMMARY

Seventy-four percent of the total Atlantic salmon spawning and rearing potential of the Tetagouche River, New Brunswick, lies above Tetagouche Falls. Salmon, although declining in

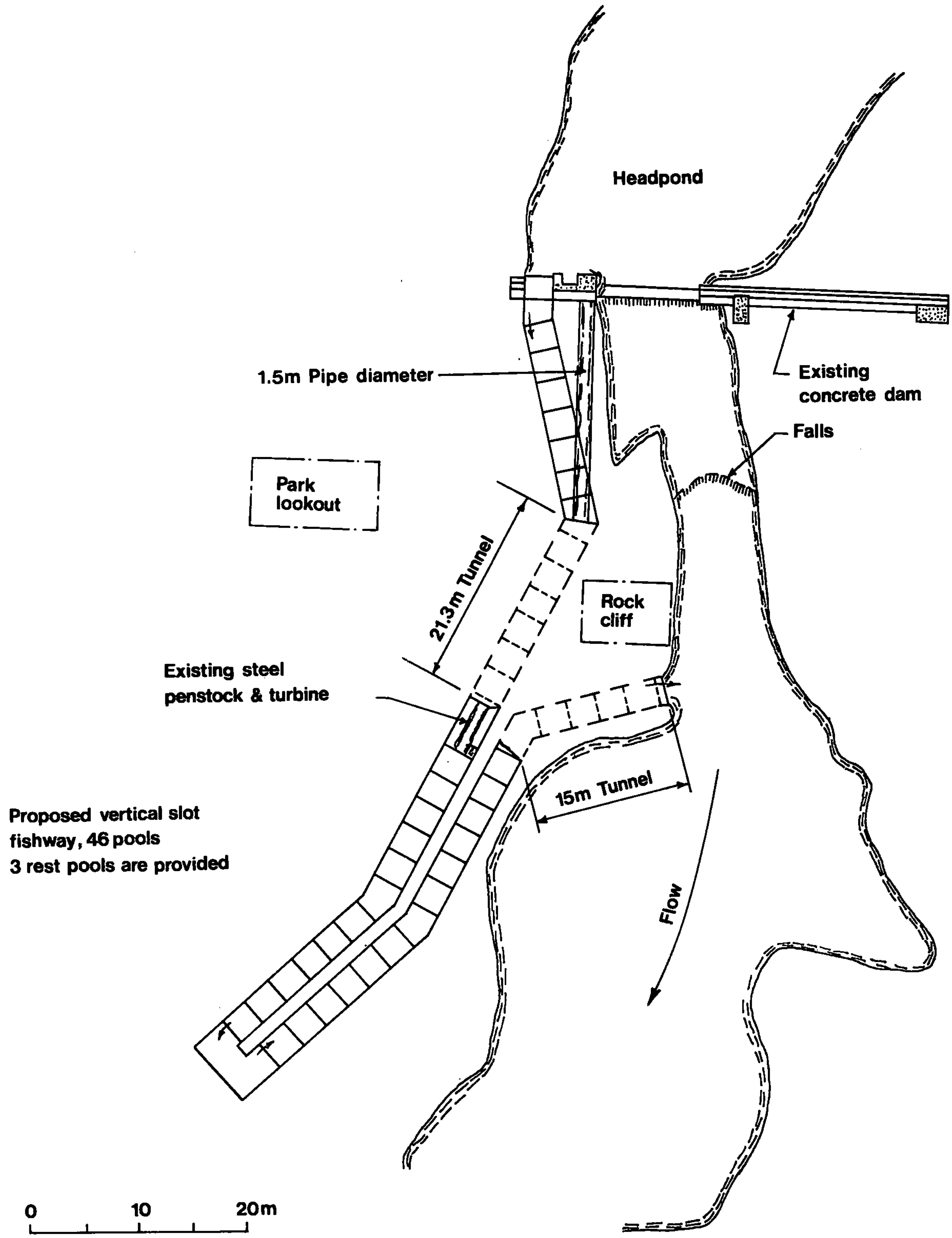


FIG. 4. Location of conceptual vertical-slot fishway at Tetagouche Falls.

numbers, still frequent the 14.5-km section below the falls. Total salmon production potential of the Tetagouche River, including the area above the falls, was estimated at 880-1,760 adult fish annually.

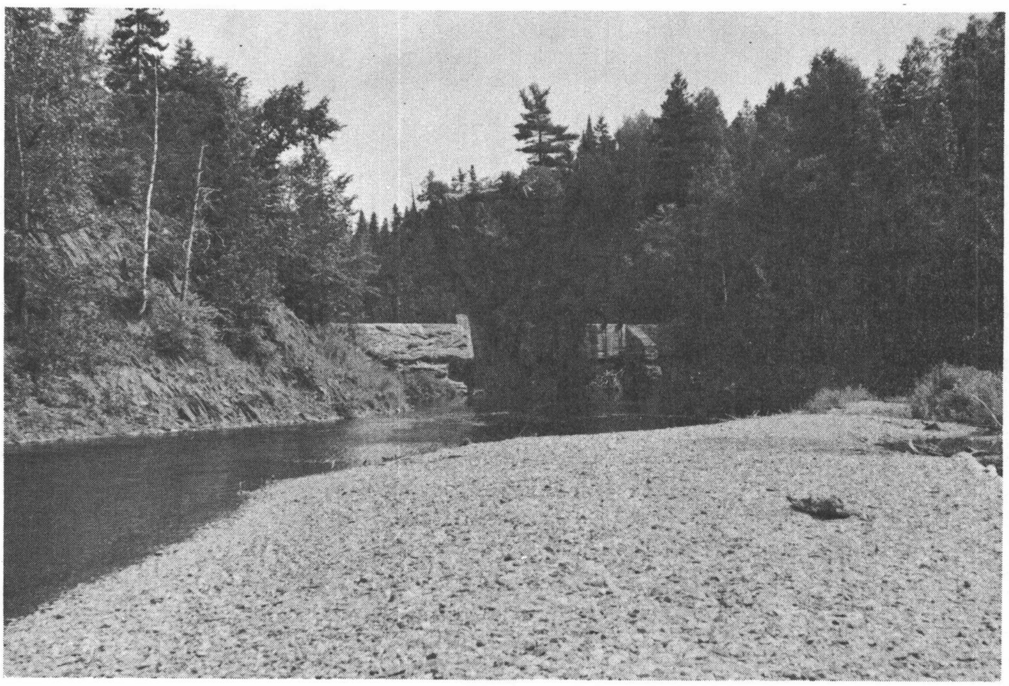
The analysis of water samples collected during the 1970 biological survey revealed the presence of heavy-metal (copper, lead, zinc) pollution. Apparently, heavy metals reach the stream through natural seepage (groundwater) and surface runoff. Plans to develop a salmon run to the upper reaches of the Tetagouche were halted, pending investigation of the effects of Tetagouche water on juvenile salmon reared in water free of heavy-metal ions, and the possibility of Tetagouche salmon acclimation to high heavy-metal concentrations.

During static bioassays conducted in 1971 at the Bedford Toxicity Laboratory, Tetagouche River fish showed no appreciable acclimation to heavy-metal concentration. In avoidance tests, Cains River fish did not show a marked tendency to avoid Tetagouche water.

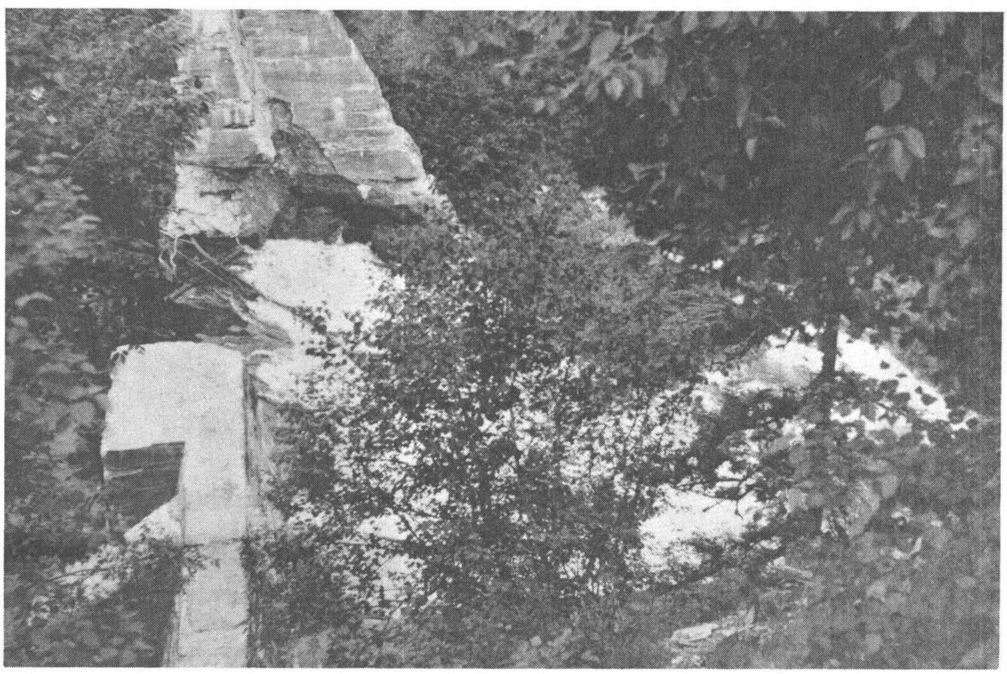
Two-hundred-hour field bioassays, conducted in 1972 on Tetagouche River, showed that hatchery yearlings reared in water free of heavy metals were unaffected by heavy metals in Tetagouche water.

Other observations of fish and bottom fauna—particularly mayflies, which are more sensitive to heavy-metal pollution than larvae of most other species—suggested a healthy aquatic community in the Tetagouche River.

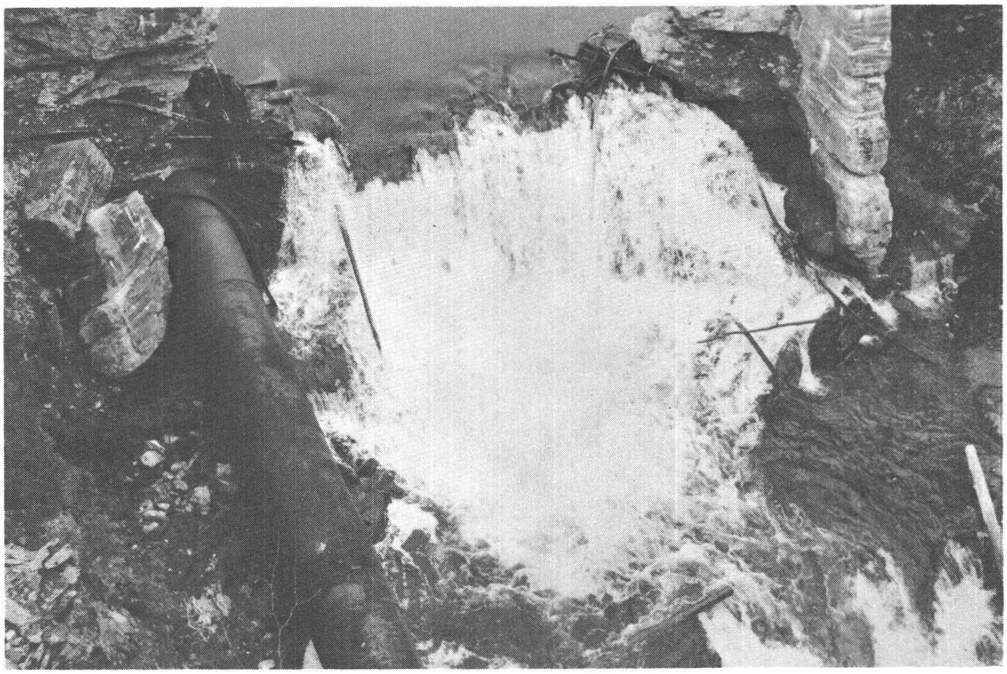
Several fish passage alternatives for Tetagouche Falls were considered. The vertical-slot fishway was deemed most practical. Notwithstanding the shortage of normal broodstock and of rearing space (artificial), the project was deemed worthwhile.



Looking downstream at the remnants of a hydro dam on the crest of Tetagouche Falls.



Side view of the concrete dam remnants.



Seen from the top of the bluff, the 10-m breached section of the dam and the 1.5-m-diameter turbine-intake pipe.

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