



A Fish Passage Problem at the Seton Hydroelectric Project in Southwestern British Columbia

L. M. Bell

To cite this article: L. M. Bell (1985) A Fish Passage Problem at the Seton Hydroelectric Project in Southwestern British Columbia, Canadian Water Resources Journal, 10:1, 32-39, DOI: [10.4296/cwrj1001032](https://doi.org/10.4296/cwrj1001032)

To link to this article: <https://doi.org/10.4296/cwrj1001032>



Published online: 23 Jan 2013.



Submit your article to this journal [↗](#)



Article views: 407



View related articles [↗](#)

A Fish Passage Problem at the Seton Hydroelectric Project in Southwestern British Columbia¹

L. M. Bell²

Abstract:

The Seton hydroelectric project, completed in 1956, is located near the Village of Lillooet, 300 kilometres north of Vancouver. During July to November each year, two discrete runs of adult sockeye salmon must migrate past the powerhouse tailrace and through a fishway at a low head dam on Seton Creek, to successfully reach their spawning grounds at Gates Creek and Portage Creek. From 1956 to 1969, Cayoosh Creek (the only tributary of Seton Creek) was diverted into Seton Lake to provide additional water for power generation. In 1969, the diversion was discontinued and Cayoosh Creek once again discharged into Seton Creek. In 1972, a decrease in the numbers of salmon reaching the spawning grounds was observed by the International Pacific Salmon Fisheries Commission (IPSC). Subsequent investigations resulted in a five-year study program to determine the cause of the fish passage problem. This paper describes the study, with emphasis on the hydrological aspects and the operating procedures recommended to control flows in Cayoosh and Seton Creeks, to alleviate the problem.

Resume:

Le projet hydroélectrique de Seton qui a été achevé en 1956, se trouve près du village de Lillooet, à 300 kilomètres au nord de Vancouver. Entre les mois de juillet et de novembre de chaque année, deux montaisons discontinues de saumons sockeye adults doivent émigrer en franchissant la galerie de fuite de la centrale électrique et en traversant une passe à poissons par un barrage à basse chute du Seton Creek, afin de réussir à atteindre leurs frayères situées à Gates Creek et à Portage Creek. Entre 1956 et 1969, le cours du Cayoosh Creek (le seul affluent du Seton Creek) était dérivé vers Seton Lake afin de fournir un apport supplémentaire d'eau pour la production électrique. En 1969, la dérivation était arrêtée et Cayoosh Creek se déversait à nouveau dans le Seton Creek. En 1972, l'International Pacific Salmon Fisheries Commission (IPSC) observait que le nombre de saumons atteignant les frayères avait diminué. Les enquêtes entreprises par la suite se sont traduites par un programme d'étude de cinq ans pour déterminer la cause du problème. L'exposé décrit l'étude, en insistant sur les aspects hydrologiques et les méthodes de mise en oeuvre recommandées pour contrôler les débits à Cayoosh et Seton Creek, dans un souci de minimiser le problème.

Introduction

Seton River, referred to locally as Seton Creek, is located on the southern outskirts of the Village of Lillooet in southwestern British Columbia. It is a short river, only 5 km long.

Originating at the eastern end of Seton Lake, it discharges into the Fraser River, approximately 300 km upstream from the Fraser Estuary (Figure 1). Since 1956, the flow in Seton Creek has been regulated by a power dam 800 m downstream from the outlet of Seton Lake.

Cayoosh Creek, the only tributary of Seton Creek, drains a mountainous area of 878 km², resulting in a discharge pattern typical of the local streams fed by glacier and snow meltwaters (Figure 2). This creek was to play an important role in the fish passage problem

¹ 37th Annual Conference, Canadian Water Resources Association, Vancouver, B.C., May, 1984.

² Hydro Resources Engineer, Generation Planning Department, B.C. Hydro, Vancouver, B.C.

that developed at the Seton hydroelectric project, some sixteen years after its completion.

Two discrete runs of sockeye salmon (*Oncorhynchus nerka*), migrate annually from the Pacific Ocean via the Fraser River and Seton Creek to their spawning grounds at Gates Creek and Portage Creek. The first run, referred to as the Gates Creek run, arrives at Seton Creek during the third week in July and continues to late August. The second run, called the Portage Creek run, arrives about mid-September and continues to early November. Data compiled by the International Pacific Salmon Fisheries Commission (IPSFC) for the period 1952 to 1974, show the average spawning populations for the dominant cycles as 10,000 for the Gates Creek run and 7,000 for the Portage Creek run. Sockeye fry from these spawning areas

rear for one year in Seton and Anderson Lakes, before commencing their downstream migration to the Pacific Ocean, where they will reside as adults for another three years before returning to their native creeks to spawn.

The Seton-Anderson system has been an important producer of sockeye as far back as the late 1800's. For example, in 1901, a dominant cycle year, the records of the B.C. Commissioner of Fisheries show the size of the spawning populations for Gates Creek and Portage Creek as 150,000 and 40,000 sockeye, respectively. During the period from 1913 to 1945, rock slides blocked the access for fish at Hell's Gate in the Fraser River Canyon and practically annihilated the runs. Fishways and tunnels built between 1945 and 1966 by the IPSFC, allowed for the restoration of the Fraser River sockeye runs, and by 1952, both the Gates and Portage Creek runs had been

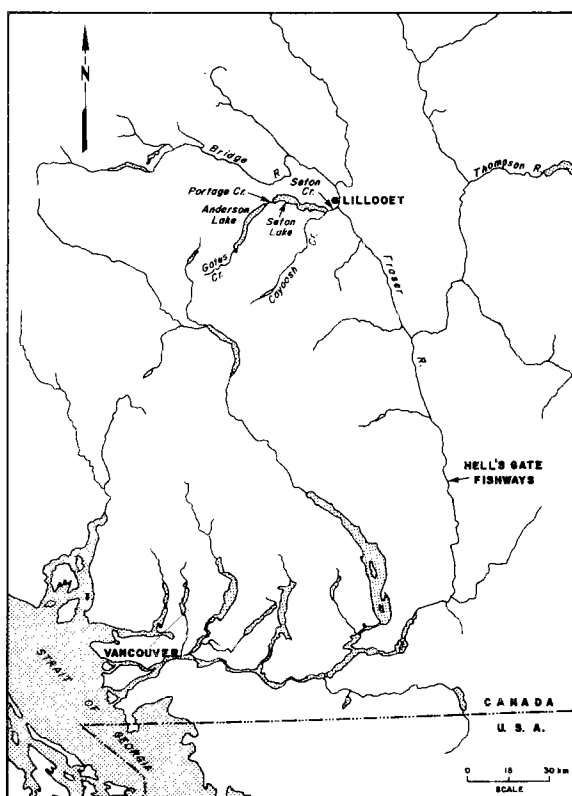
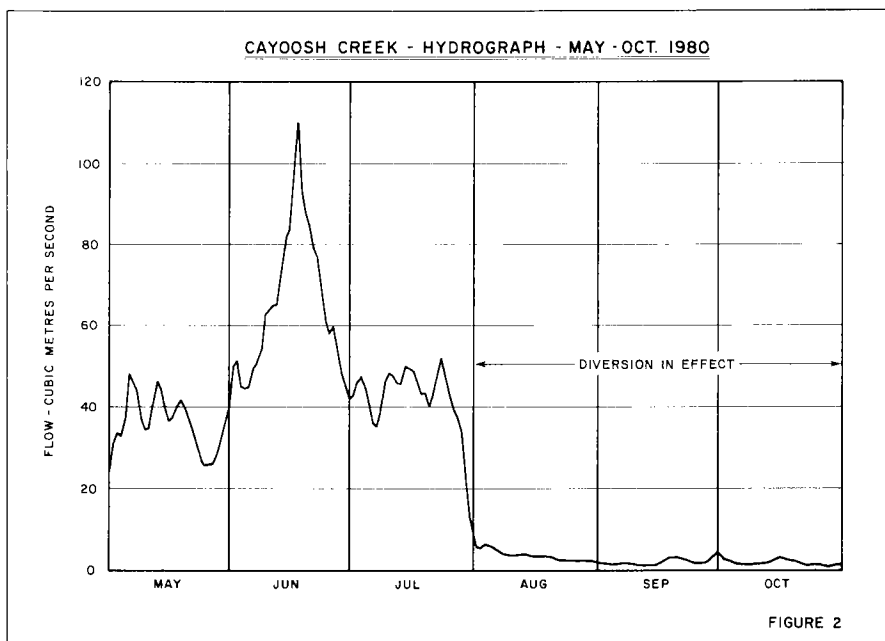


FIGURE 1. LOCATION OF SETON CREEK



re-established (Figure 3). In 1968, the IPSFC constructed the Gates Creek spawning channel, which, with natural spawning in Gates Creek provides the potential for 49,000 spawning sockeye, or about five times the present spawning population.

The Project

The Seton hydroelectric project (Figure 4) was completed in 1956. It is part of the Bridge River development (Figure 5) built between 1946 and 1960, consisting of four generating stations, Lajoie, Bridge 1, Bridge 2 and Seton. With a capacity of 42 MW, the Seton project provides an annual average energy capability of 340 GWh for the southwestern B.C. grid system.

The main features of the project are:

- a low head, 8 m high concrete dam on Seton Creek, 800 m downstream from the outlet of Seton Lake
- a 4 km, concrete lined power canal operating with an average water depth of 4.5 m and an average annual power flow of 113 m³/sec.
- a powerhouse housing a single 42 MW vertical-shaft Francis turbine operating under an average head of 48 m.

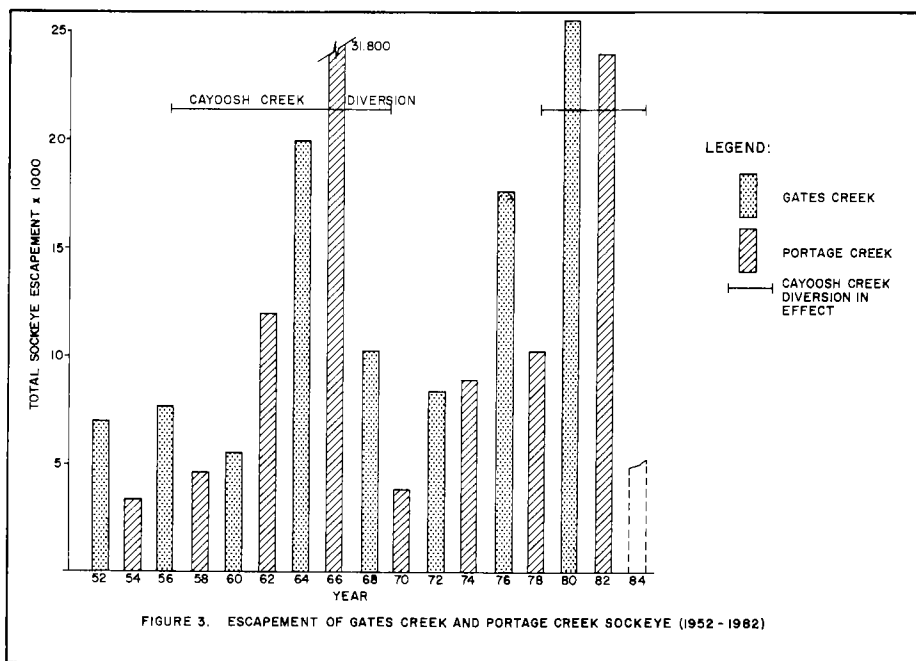
- a tailrace channel extending approximately 76 m from the powerhouse to the Fraser River.

A vertical slot fishway, 100 m long by 2.4 m wide provides access for salmon spawning upstream of the dam. Attraction flow at the entrance to the fishway is provided by a fishwater sluice, controlled by a 1.5 m by 1.5 m gate, 4 metres below the maximum forebay elevation. An energy dissipating chamber is located immediately below the sluiceway. The sluice gate is also used to control the flows in Seton Creek, downstream of the dam, as specified in Hydro's Conditional Water Licence. Flows required by this licence are, a minimum of 11.3 m³/sec during salmon spawning runs and a minimum of 5.6 m³/sec at all other times.

A radial gate spillway, designed to pass 226 m³/sec is located at the north end of the dam. A five siphon spillway section, with four siphons rated at 25.5 m³/sec and one at 19.8 m³/sec is located between the radial gate the fishwater sluice. At the south end of the dam a gated intake structure controls the flows in the power canal.

Cayoosh Creek Diversion

In 1957, to provide additional water for power



generation at the Seton generating station, Cayoosh Creek was diverted into Seton Lake. This was accomplished by constructing a 4 m high timber crib dam on Cayoosh Creek and a 490 m long tunnel through the divide between Cayoosh Creek and Seton Lake. The diversion was operated until 1969, at which time it was no longer required for power purposes. The tunnel was sealed, the dam was breached and once again Cayoosh Creek was allowed to flow through its natural course into Seton Creek. It was this change in the Seton flow regime that was to ultimately cause the fish passage problem to which this paper is addressed.

The Problem

As mentioned previously, two runs of adult sockeye salmon must successfully migrate past the Seton generating station and the Seton dam, to reach their spawning grounds above Seton Lake. After spawning, sockeye fry rear for one year in Seton Lake, and thus, when migrating seaward as smolts, have imprinted in their olfactory senses, the characteristics of Seton Lake water. Later as adults returning from the ocean to spawn, they will use this imprint to enable them to identify Seton Creek as they migrate up the Fraser

River.

To reach Seton Creek the spawning runs must pass the tailrace of the Seton generating station, where they first encounter pure Seton Lake water, discharging into the Fraser River from the turbine draft tube. The runs, sensing Seton water, tend to school in the tailrace, with a resulting delay in their upstream migration.

In 1972, the International Pacific Salmon Fisheries Commission, analysing their management records of Fraser River salmon stocks, discovered that the number of sockeye passing through the Seton fishway was much lower than the calculated number escaping the commercial fishery in the Strait of Georgia and lower Fraser River. Their data showed that in 1972, of the estimated 15,000 sockeye that escaped the commercial fishery, only 8,800 migrated through the Seton fishway. This suggested that 40 percent of the Gates Creek run were delayed in the tailrace to the extent that they could no longer continue on their spawning migration.

In 1973, the IPSFC intensified their studies in an effort to correlate fishway counts with plant operating conditions. Systematic observations were made to determine the relative abundance of fish in the tailrace, where fishway counts were taken at 15 minute intervals,

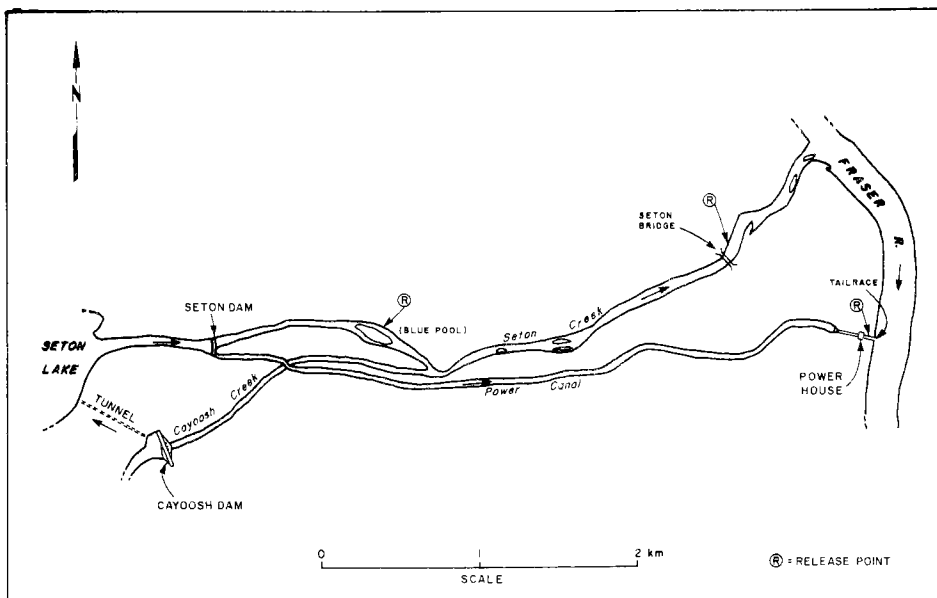


FIGURE 4. LAYOUT OF SETON CREEK HYDROELECTRIC PROJECT AND LOCATION OF RELEASE POINTS FOR RADIO-TAGGED FISH

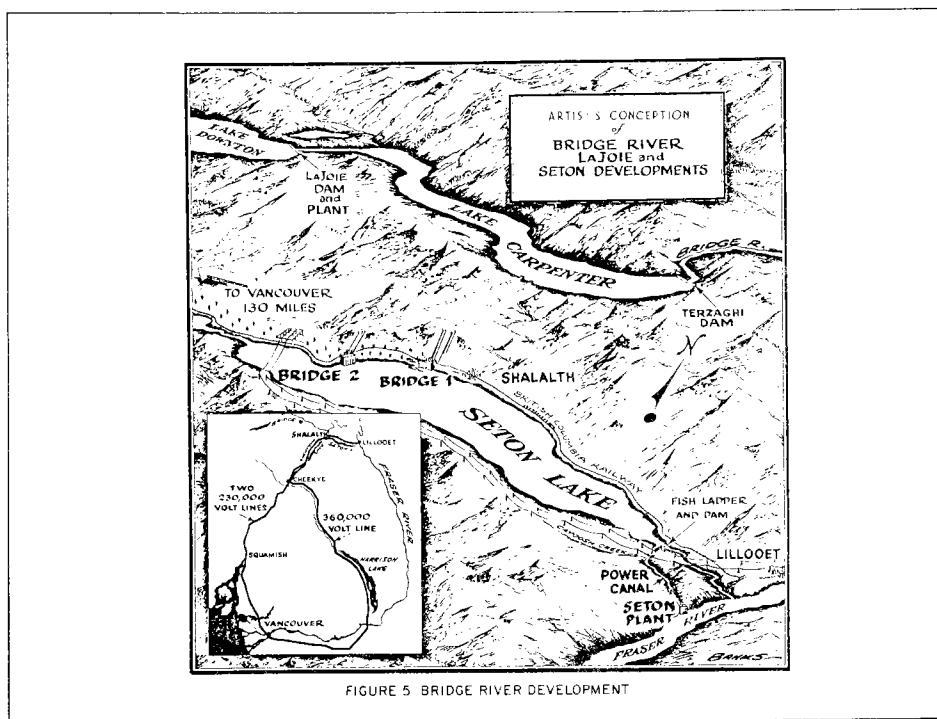


FIGURE 5 BRIDGE RIVER DEVELOPMENT

throughout the day. B.C. Hydro cooperated with the Commission by scheduling plant operation to maximize the opportunities for comparing the numbers of fish migrating, under various hydraulic conditions. The upstream migration of the sockeye was studied in relation to:

- amounts of spill over Seton dam
- spill duration
- length of powerhouse shutdowns
- plant output
- tailrace elevation
- tiding of fish migration

Observations continued in 1974 and 1975. Test and control groups of fish were tagged and released to measure loss of fish in the tailrace. Divers were used to study the behaviour of fish in the tailrace, and also in the draft tube, during powerhouse shutdowns.

In 1976, the IPSFC issued a report entitled "Tailrace Delay and Loss of Adult Sockeye Salmon at the Seton Creek Hydroelectric Plant". It listed six main observations, namely:

1. Adult sockeye populations destined for spawning areas in Gates and Portage Creek are being seriously depleted because the fish are unable to migrate past the tailrace of the Seton G.S. without delay, injury and mortality, despite the provisions of the required minimum operating conditions, which consist of a minimum discharge of 11.3 m³/sec at Seton dam and tri-weekly powerhouse shutdowns of not less than 3 hours duration.
2. Some sockeye remain in the tailrace during powerhouse shutdowns, possibly because they are attracted to leakage of Seton Lake water (approximately 0.5 m³/sec into the tailrace through the turbine wicket gates and from seepage).
3. The spill discharge at Seton dam was the most important factor affecting migration of sockeye out of the tailrace.
4. Velocities in the draft tube were low enough to permit sockeye to enter the draft tube at minimum loads of about 2 MW, resulting in fish being killed or severely injured by the runner.
5. Injuries suffered by fish attempting to swim into the leakage flow at the wicket gates during powerhouse shutdowns, could be avoided by injecting air into the draft tube to depress the water surface to the bottom of the vertical section of the draft tube.

6. On the basis of the number of fish escaping through the commercial fishing area of the lower Fraser River, it was estimated that 40 percent of the 1972 Gates Creek sockeye run and 60 percent of the 1974 Portage Creek sockeye run failed to reach the spawning ground.

Following discussions between the IPSFC, the Department of Fisheries and Oceans and B.C. Hydro, a program of field studies was undertaken to;

- Determine the factors, particularly the flows in Seton Creek, that would clear the tailrace of adult salmon, and
- To test the attraction of fish to varying combinations of Seton Creek and Fraser River waters.

These studies, funded by B.C. Hydro, were carried out over a period of five years from 1978 to 1982, by IPSFC personnel working closely with B.C. Hydro biologists and engineers.

Study Methods and Results

Initially the studies concentrated on the tracking of fish with a base spill at Seton Dam of 11.3 m³/sec, and short pulse spills of up to 51 m³/sec. Fish tagged with Petersen tags, for visual identification, and radio tags for radio tracking, were released in three different locations, (1) the tailrace, (2) Seton bridge and (3) the "blue pool" (Figure 4). Fishway counts at the Seton Dam were made for 15 minutes every 1.5 hours during daylight hours. These were later compared with tailrace index counts, to estimate the abundance of fish in the tailrace. The counts were made by 10-minute observations along both the north and south banks of the tailrace four times a day during normal plant operations.

An electronic multiple tunnel resistivity fish counter was installed at the Seton Dam in 1981, thus providing an accurate twenty-four hour fishway count. Radio-telemetry studies were carried out using fish module transmitters, or radio tags. These tags weigh 4.5 grams and operate on a frequency in the 49 MHz range. Tracking of fish was done with LA12 radio receivers and directional antennae.

The 1978 studies showed that the migration of radio-tagged sockeye upstream from the powerhouse was dependent upon the magnitude and continuity of the spill discharge. Discharges greater than 28.3 m³/sec, that is two to three times the operating requirement of 11.3 m³/sec, significantly reduced the

delay of fish in the tailrace.

Additional radio-tagging experiments carried out with Gates Creek sockeye in 1979, confirmed that fish released in Seton Creek below the Cayoosh–Seton confluence, would migrate upstream at high spill discharges, but when the spill was only 11.3 m³/sec would drop downstream and return to the tailrace. Thus it was hypothesized that following acclimation to Seton Lake water in the tailrace, the sockeye were not attracted to Seton Creek when it contained a high percentage of Cayoosh Creek water.

As an experiment, in September 1979, prior to the Portage Creek run, B.C. Hydro constructed a temporary rockfill diversion dam on Cayoosh Creek. The diversion tunnel was re-opened and Cayoosh Creek was once again diverted into Seton Lake. The results were remarkable.

With a normal spill discharge at Seton Dam, and with the residual flow in Cayoosh Creek reduced to 7–13 percent of the total Seton–Cayoosh discharge, the average delay of Portage Creek fish in the tailrace was reduced to 28.7 hours, from an average of 92.3 hours during the Gates Creek run. Of the 27 fish released in the tailrace and 18 released in Seton Creek below its confluence with Cayoosh Creek, all migrated to Seton Dam, as compared to the Gates Creek run, when 43 percent of the fish released in the tailrace failed to migrate, and 10 fish released in Seton Creek below its confluence with Cayoosh Creek, dropped back downstream to the tailrace.

Since 1979, Cayoosh Creek has been diverted annually into Seton Lake, from the end of July to the end of November, with a resulting decrease in delay of sockeye in the tailrace.

In 1980, 1981 and 1982, radio-telemetry studies were undertaken with varying amounts of Cayoosh water in the Seton–Cayoosh mix, below the confluence of Seton and Cayoosh Creeks. At the same time field laboratory studies were carried out in a controlled preference trough apparatus, to quantify the response of Gates and Portage Creek sockeye to various mixtures of Seton and Cayoosh Creek water. The design of the apparatus was similar to that described by Sutterlin and Gray (1973) for testing the homing of Atlantic salmon to a hatchery.

The apparatus was set up adjacent to Cayoosh Creek, immediately upstream of the power canal aqueduct across Cayoosh Creek. Basically it consisted of a central hold-

ing chamber, 1.8 m in diameter by 0.6 m deep, connected to two rectangular troughs, 3 m long, 0.75 m wide and 0.5 m deep. A system of valves allowed the operator to control the proportions of Seton and Cayoosh water in the troughs and holding chamber. Seton Lake water was obtained by siphoning water from the power canal, and Cayoosh water obtained by gravity flow from Cayoosh Creek.

Fish captured in the tailrace were transported to the central holding pool. Gates between the central pool and the troughs were opened and the behaviour of the fish observed from a vantage point on the canal aqueduct about 15 m above the apparatus. Tests were conducted with Seton water versus mixtures of Seton and Cayoosh water containing 0, 10, 20, 33, 50 and 100 percent Cayoosh water.

Result of the preference trough studies indicated that Gates Creek sockeye tended to reject Seton Creek water diluted with 20 percent or more Cayoosh water. Portage Creek sockeye appeared to be more sensitive than the Gates Creek fish, although their response was variable. Sometimes they rejected Seton water with only 10 percent Cayoosh water, while other times they accepted up to 20 percent Cayoosh water, especially during the last third of the run. The reason for this is not yet known.

The Solution

The partial diversion of Cayoosh Creek into Seton Lake, to reduce the amount of Cayoosh water in the Seton–Cayoosh mix to a level acceptable by both Gates Creek and Portage Creek sockeye, is now considered by the Department of Fisheries and Oceans and the IPSFC as an acceptable solution to the tailrace delay problem. Starting last year, 1983, B.C. Hydro agreed to operate the Seton G.S. under a number of plant operating constraints recommended by the IPSFC and DFO.

1. Provide a minimum spill discharge of 11.3 m³/sec through the fishway and fishwater sluice, during the expected adult salmon migration period July 20–November 15.
2. During the sockeye migration periods July 20–August 31 and September 28–November 15.
 - a) Limit the Cayoosh Creek component of the Seton–Cayoosh discharge, by diverting Cayoosh Creek into Seton lake and by spilling additional water at Seton Dam, to,
 - i) Twenty percent or less during the Gates

- Creek migration approximately July 20–August 31, and
- i) Ten percent or less during the Portage Creek migration, approximately September 28–November 15.
 - b) Operate Seton G.S. at not less than 38 MW or alternatively shut down the plant.
 - c) Inject air into the draft tube during plant shutdowns, to depress the draft tube water surface to approximately elevation 180 m, to deter fish from entering the draft tube.
 - d) Restrict radial gate spill to 28.3 m³/sec except when all siphons are operating.
3. After the sockeye migration, provide a spill of not less than 5.6 m³/sec in Seton Creek.

Construction of a permanent facility to control the flow of Cayoosh Creek during the sockeye spawning runs has been estimated to cost \$3,000,000, based on 1982 prices. However, based on the actual costs to date for installing and removing the temporary dam, it would be difficult to provide the economic justification for constructing a permanent structure. For the present, therefore, the temporary diversion dam is installed annually during the sockeye migration period and removed before the spring freshet.

Acknowledgements

The author extends his thanks to B.C. Hydro for permission to publish this paper, and to his colleagues Dr. R. G. Ferguson and Mr. C. E. Walker, of the Aquatic Studies Section, who provided invaluable expertise and guidance during the studies.

Full recognition is given to the work of the International Pacific Salmon Fisheries Commission, especially that of Mr. F. J. Andrew, their Chief Engineer, and Mr. M. R. Fretwell, the project biologist, who made a significant contribution to the resolution of this particular problem.

Fretwell, M. R. and S. Hamilton. 1983. "Migration of adult sockeye salmon at Seton Creek hydroelectric plant in 1982". *Int. Pac. Salmon Fish. Comm.* Unpublished 39 pp.

Sutterlin, A. M. and R. Gray. 1973. "Chemical basis for homing of Atlantic Salmon (*Salmo salar*) to a hatchery". *J. Fish. Res. Board. Can.* 30:985-989.

References

Anonymous. 1976. "Tailrace delay and loss of adult sockeye salmon at the Seton Creek hydroelectric plant". *Int. Pac. Salmon Fish. Comm.* 74 pp.

Fretwell, M. R. 1981. "Migration of adult sockeye salmon at Seton Creek hydroelectric plant in 1980". *Int. Pac. Salmon Fish. Comm.* Unpubl. 28 pp.