

Radio Tracking Chinook Salmon to Determine Migration Delay at Whitehorse Rapids Dam

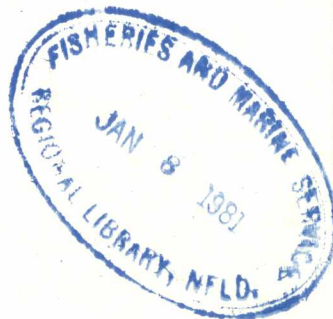
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Fisheries and Oceans
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FISHERIES AND MARINE SERVICE

MANUSCRIPT REPORT NO. 1459

October, 1980

RADIO TRACKING CHINOOK SALMON
TO DETERMINE MIGRATION DELAY AT
WHITEHORSE RAPIDS DAM

By

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ABSTRACT

CLEUGH, T.R., AND L.R. RUSSELL. 1980. Radio tracking chinook salmon to determine migration delay at Whitehorse Rapids Dam. Fish. & Mar. Ser. Man. Rept. #1459: 43 pp.

Migration pattern of radio-tagged adult chinook salmon (*Oncorhynchus tshawytscha*) were monitored during August, 1979 in the upper Yukon River, Yukon Territory. Escapement, migration pattern, travel time, spawning areas, and delays caused by the hydroelectric facilities and physical obstructions were assessed.

Eleven hundred and eighty-four chinook salmon migrated through the Whitehorse Rapids Fishway in August, 1979 and twenty-one fish were radio-tagged. Migrating salmon used both sides of the river and the hydro facilities and physical obstructions resulted in some delay in upstream migration. The minimum and maximum observed delay which occurred at the hydro facilities was 10 hours and 9 days respectively, with a mean delay of 3 days; average delay through the fishway was 7 hours. Fifteen tagged fish were located on the spawning grounds.

Key words: Hydroelectric facilities, delay, chinook salmon, radio-tagging, Yukon River

RÉSUMÉ

On a contrôlé en août 1979, les habitudes migratoires de saumons quinnats adultes (*Oncorhynchus tshawytscha*), marqués électroniquement dans la partie supérieure du fleuve Yukon (Territoire du Yukon). On a pu ainsi évaluer la remonte, les habitudes migratoires, le temps de remonte, les frayères et les retards causés par les installations hydro-électriques et les obstructions physiques.

Mille cent quatre-vingt-quatre saumons quinnats ont emprunté l'échelle à poisson des rapides Whitehorse en août 1979 et 21 poissons ont été marqués électroniquement. Les saumons en migration utilisaient les deux côtés de la rivière et les installations hydro-électriques et les obstructions physiques constituaient des obstacles qui retardaient la migration vers l'amont. Les retards minimaux et maximaux observés aux installations hydro-électriques étaient de 10 heures et 9 jours respectivement, la moyenne étant de 3 jours; le retard moyen causé par l'échelle à poisson était de 7 heures. Quinze poissons marqués ont été observés dans les frayères.

Mots clés: Installations hydro-électriques, retard, saumon quinnat, marquage électronique, fleuve Yukon

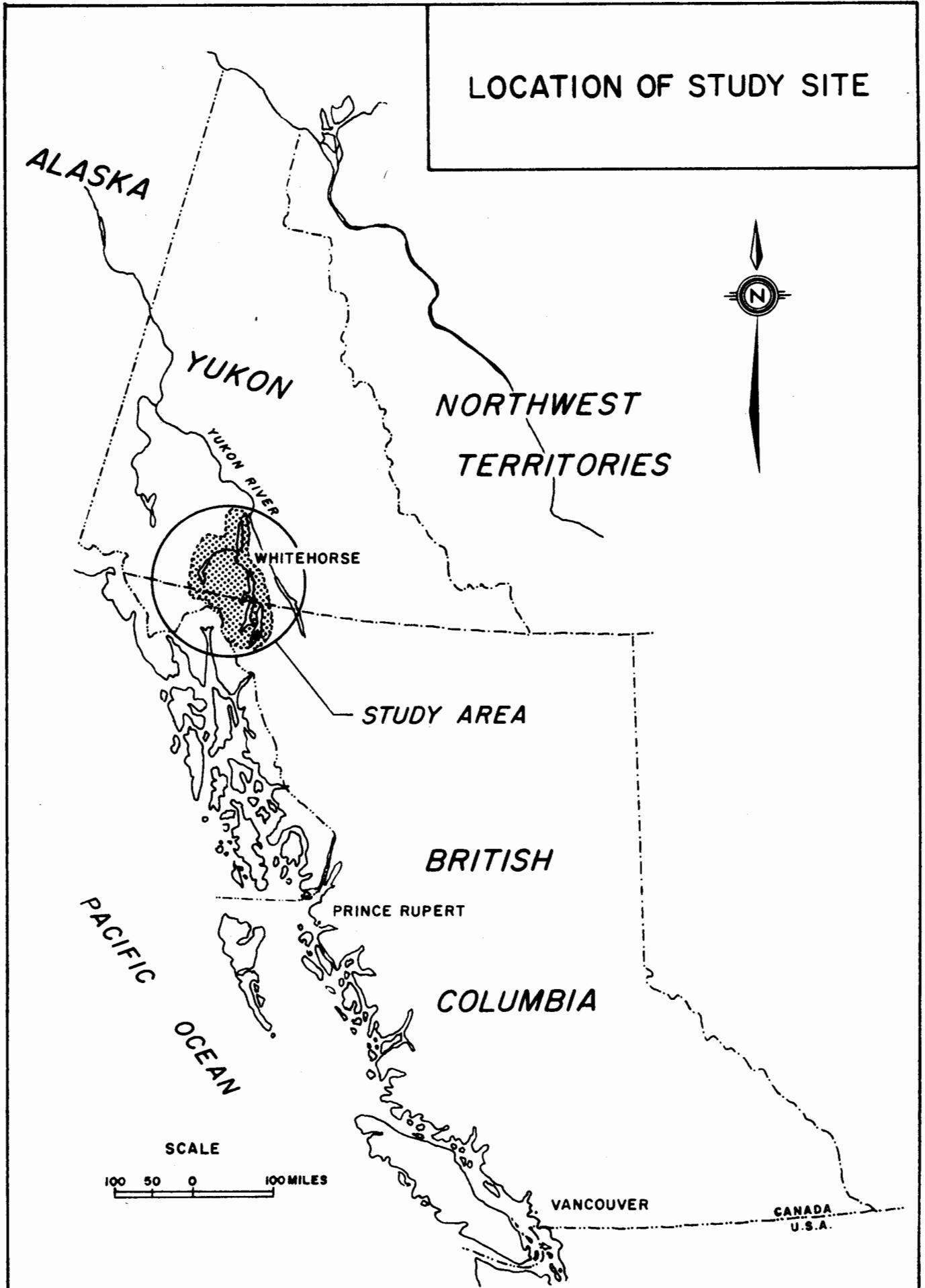
1. INTRODUCTION

The Fisheries Service has been concerned about the survival of the chinook salmon stocks upstream of Whitehorse since 1956 when it was first informed of Northern Canada Power Commission's intention to develop the hydroelectric potential of the Yukon River at Whitehorse Rapids (Figure 1). This concern has increased in the intervening twenty-three years particularly in the light of the application by the Northern Canada Power Commission for a water licence to install a fourth turbine at the generating station.

Over the past decade it has become increasingly apparent that adult chinook salmon are having difficulty in approaching fishways below impoundments. This may be due to large spillway releases, obstructions, and/or decreased attraction to the fishway. On the Columbia River System these attraction and delay problems have been investigated on several dams throughout the 1970's (Monan and Liscom, 1971, 1973, 1974a, 1974b, 1975). Similar problems have been investigated in the Northern Pacific Region (Gordon et al., 1960; Lister, 1960; Madison et al., 1972; Stasko et al., 1973).

In addition to the poor escapement in 1958 caused by the total barrier to migration resulting from dam construction and the probability of high turbine mortality of chinook smolts (Lister, 1960), it was suggested that a substantial loss of fish may occur due to adult salmon delays at the Whitehorse Rapids damsite. These delays may be a result of several physical factors which include:

1. High water velocities in the vicinity of the fishway entrance.
2. Large rock outcrops on the downstream side of the fishway entrance.
3. High velocity flows in the mainstem of the river at the fishway.



4. Strong turbine attraction flows and inadequate bypass channel flows.
5. Improper barrier dam design.

In order to estimate the extent of delays due to these physical factors the pattern of salmon migration must be documented. This information can be separated into three categories:

1. Delays associated with upstream migration (at the damsite).
2. Pattern of migration above and below the impoundment.
3. Success of fishway passage.

The present study proposed to investigate possible migration delays using implanted radio tags and tracking the migrating salmon from the point of release in the Yukon River below the dam up the river, through the power plant tailrace area and over the Whitehorse Rapids dam to the spawning grounds.

Radio-telemetry methods used to study fish migration have become increasingly reliable. Previous workers (Monen et al., 1979; Monen & Liscom, 1971, 1973, 1974a, 1974b, 1975) have successfully used internal radio transmitters to study adult chinook salmon in the Columbia River. Radio-telemetry has also been used successfully to track rainbow trout (Salmo gairdneri) in Lake Superior (Winters et al., 1973) and to plot the movements of Atlantic salmon (Salmo saler) and American shad (Alosa sapidissima) (Knight et al., 1977).

2. DESCRIPTION OF STUDY AREA

2.1 Introduction

In December 1956 the Department of Fisheries and Oceans were informed of a proposed hydro power project at Whitehorse Rapids, Yukon Territory. This development required that a dam be constructed across the Yukon River (Figure 2) blocking the migration route of chinook salmon (Oncorhynchus tshawytscha) which spawn in the upper watershed. Initial impact studies recognized the immediate need for upstream fish passage facilities to sustain the salmon population. Negotiations between the Department of Fisheries and the proponent (Northern Canada Power Commission) resulted in the construction of temporary fishway facilities at Whitehorse Rapids in 1958 and permanent facilities by June 1959. In 1974 the Department of Fisheries was asked by the Comptroller of Water Rights for the Yukon on behalf of the Yukon Territorial Water Board to assess potential problems associated with the proposed installation of an additional (fourth) turbine at the power generating facility. This assessment was forwarded to the Water Board in 1975, and the modifications to the existing facility suggested by the Department of Fisheries have been incorporated in the proposal for a fourth turbine.

2.2 Existing and Proposed Facilities

To date the hydroelectric facilities at Whitehorse Rapids include a low-head dam and spillway, a three turbine power plant with an operating head of 20.3 metres (62 feet), and a power canal from Schwatka Reservoir to the power plant (Figure 2). Two turbines were installed in 1958 and the third unit was completed in 1969. The fish facilities include: a collection gallery and a transportation channel to enable the adult migrants to bypass the powerhouse and lead them back to the Yukon River below the storage dam; a barrier dam across the river at the fishway entrance; and a 394 metre (1,200 foot) fishway along the east side of the river to pass fish 18 vertical metres over the dam, see Plates 1 and 2. A complete description of these facilities is given in Gordon et al. (1960).

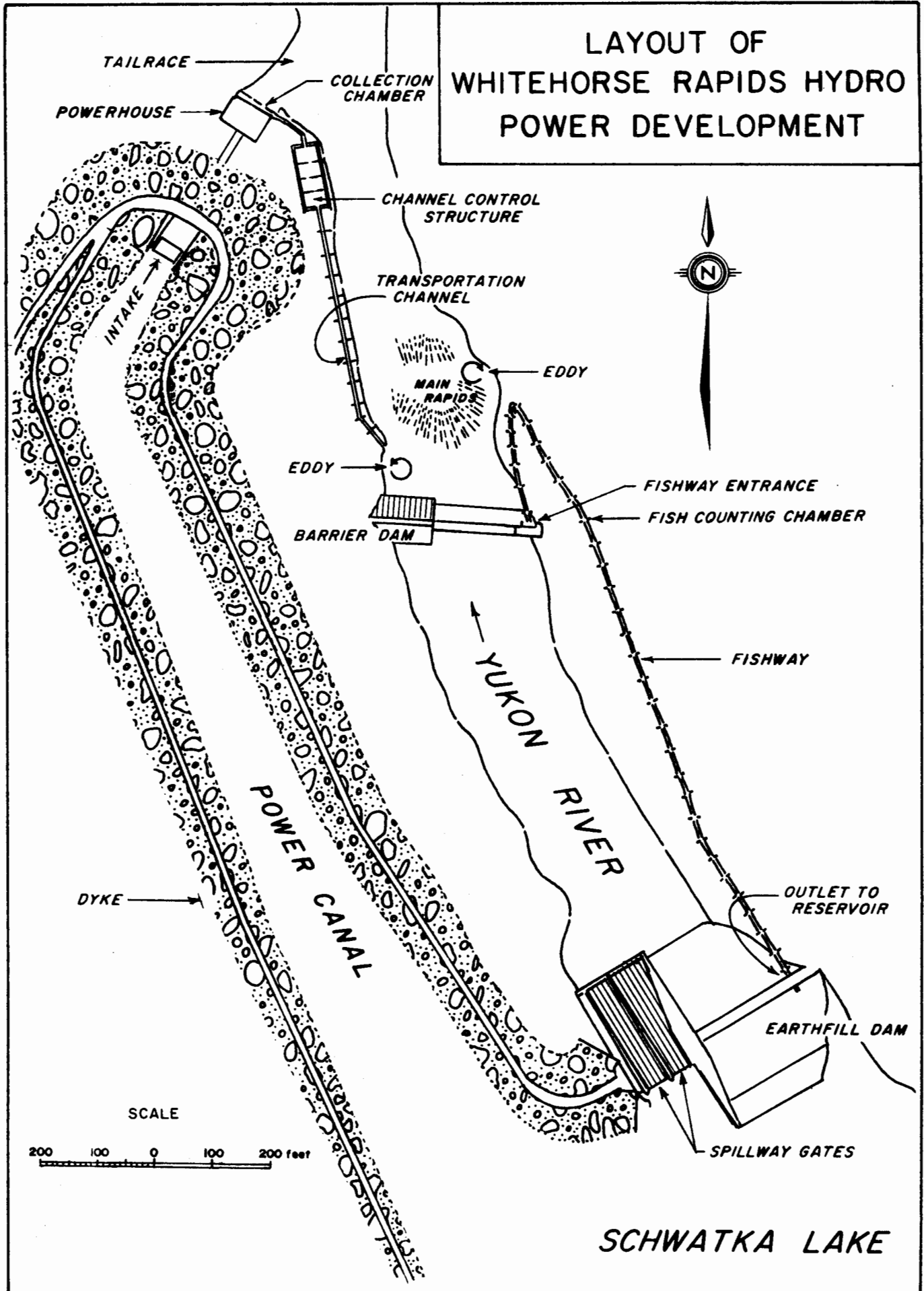




PLATE 1: Whitehorse Rapids hydro-electric power development



PLATE 2: Whitehorse Rapids fishway

The proposed additional turbine would be located immediately below the spillway. A tailrace would be excavated from the proposed power plant to below the present barrier dam. These modifications would likely involve substantial structural changes to the existing fishway.

2.3 Salmon Resource

Yukon River chinook salmon generally arrive at the Whitehorse fishway on 1 August, after an approximate 1,900 mile freshwater migration and finish migrating by 1 September. Spawning is usually completed by 15 September in Michie Creek, the only known significant nursery area above the development (Cleugh et al., 1978). The salmon at Whitehorse average 6.8 Kg in weight, although some reach a maximum of 27 Kg. Length comparisons at Whitehorse Rapids show males to be 52 to 95 cm and females 75 to 100 cm; mean lengths for females are 85 cm and 75 cm for males in 1973, 1974 and 1978. The sex ratio at the fishway is variable, (see Table 1), ages range from 4 to 7 years; males are usually ages 4 or 5 and females are predominately age 6. The freshwater residence period is usually 2 years.

Adult chinook salmon counts made at the Whitehorse Rapids fishway are shown in Table 1. The mean escapement population for the past 22 years is 605 salmon. The initial 10 years (1958-1967) had a mean count of 758 salmon whereas the period (1968-1977) had a lower mean of 381 salmon (Table 2). The most recent escapements of 725 (1978) and 1,184 (1979) fish probably reflect reduced ocean fishing pressure due to the new 200 mile fishing limit (see Table 3). If the salmon counts are separated into 6 year cycles, beginning in 1959 (the first year of successful fishway operation) and the mean yearly population is computed, a significant population decline is apparent.

TABLE 1: NUMBERS OF CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) MIGRATING THROUGH WHITEHORSE RAPIDS FISHWAY - 1958 TO 1979

Year	Count	Year	Count	% males
1958	225*	1968	407	-
1959	1,054	1969	334	86
1960	660	1970	625	48.7
1961	1,068	1971	856	46.2
1962	1,500	1972	392	61
1963	484	1973	220	61.5
1964	587	1974	273	-
1965	903	1975	313	52.7
1966	563	1976	121	58.5
1967	533	1977	272	57
\bar{x}	758	\bar{x}	381	-
		1978	725	57
		1979	1,184	-

* The 1958 total count includes 1 fish through the temporary fishway and 224 fish netted and transported over the dam.

TABLE 2: MEAN POPULATION OF SALMON
MIGRATING PAST WHITEHORSE RAPIDS

<u>Year</u>	<u># of Years</u>	<u>Mean</u>
1959 to 1964	6	892
1965 to 1970	6	659
1971 to 1976	6	362
1958 to 1967	10	758
1968 to 1977	10	381
1978 & 1979	2	955
1958 to 1979	22	605

TABLE 3: PERCENT RELATIONSHIP OF DOWNSTREAM MIGRANT CHINOOK SALMON TO RETURNING ADULTS, WHITEHORSE RAPIDS FISHWAY, 1959 - 1979.

Escapement Year ¹	Fishway Count	Number of Females	Total Number of eggs @5000 eggs/♀ x10 ⁶	10% Fry Survival x10 ⁵	10% Smolt Survival x10 ⁴	Adult Return	% Survival
1959	1,054	527	2.64	2.64	2.64	587	2.22
1960	660	330	1.65	1.65	1.65	903	5.47
1961	1,068	534	2.67	2.67	2.67	563	2.11
1962	1,500	750	3.75	3.75	3.75	533	1.42
1963	484	242	1.21	1.21	1.21	407	3.36
1964	587	294	1.47	1.47	1.47	334	2.27
1965	903	452	2.26	2.26	2.26	625	2.77
1966	563	282	1.41	1.41	1.41	856	6.07
1967	533	267	1.34	1.34	1.34	392	2.93
1968	407	204	1.02	1.02	1.02	220	2.20
1969	334	167	0.84	0.84	0.84	273	3.25
1970	625	313	1.57	1.57	1.57	313	1.97
1971	856	428	2.14	2.14	2.14	121	0.57
1972	392	196	0.98	0.98	0.98	272	2.78
1973	220	110	0.56	0.56	0.56	725	12.95 ²
1974	273	137	0.69	0.69	0.69	1,184	17.16 ²
1975	313	155	0.78	0.78	0.78	-	-
1976	121	61	0.31	0.31	0.31	-	-
1977	272	136	0.68	0.68	0.68	-	-
1978	725	363	1.82	1.82	1.82	-	-
1979	1,184	592	2.96	2.96	2.96	-	-

¹ Assumes age 6₂.

² Changes in 200 mile fishing limit affected the 1973 and 1974 brood years.

2.4 Hydrology

The mean monthly streamflows recorded in the Yukon River at Whitehorse during the 30 year period 1943-1973 are given in Table 4. Mean daily flows recorded at Whitehorse during the 1979 radio-tagging study are also presented. The mean flow recorded during August 1979 (19,300 cfs) was 1,800 cfs greater than the 30 year average mean August flow.

2.5 Climatic Conditions

The climate of the Whitehorse area has been summarized from the monthly record of meteorological observations in northern Canada (Environment Canada, Atmospheric Environment) and is presented in Table 5.

Climatic information averaged over the period 1941-1970 indicates that the mean annual daily maximum and minimum temperatures at Whitehorse are 4.2 and -5.9°C respectively. The mean annual precipitation is 26.1 cm of which 12.1 cm falls as snow and the mean annual number of bright sunshine hours is 1,825.

2.6 Water Quality

Water quality parameters measured in the Yukon River in 1977 at Whitehorse Rapids Dam and the Lewes Dam on Marsh Lake (Department of Indian and Northern Affairs, Whitehorse, Y.T.) are given in Table 6. None of the parameters measured were found in concentrations considered to be lethal or sublethal to salmonid fish (McKee & Wolf, 1963).

TABLE 4: YUKON RIVER - STREAMFLOWS AT WHITEHORSE

MEAN MONTHLY STREAMFLOWS RECORDED 1943-1973 (cfs)

<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Overall Mean</u>
3,750	3,310	2,980	2,780	4,690	10,600	15,500	17,500	16,100	12,500	6,830	4,610	8,440

MEAN DAILY STREAMFLOWS RECORDED DURING 1979 RATIO TAGGING STUDY (cfs)

<u>August</u>		<u>August</u>		<u>September</u>	
1	18,800	16	19,500	1	19,500
2	18,800	17	19,500	2	19,300
3	18,800	18	19,400	3	19,300
4	18,800	19	19,400		
5	18,900	20	19,500		
6	19,000	21	19,500		
7	19,100	22	19,100		
8	19,100	23	19,000		
9	19,200	24	19,200		
10	19,400	25	19,500		
11	19,400	26	19,500		
12	19,300	27	19,500		
13	19,300	28	19,500		
14	19,400	29	19,500		
15	19,400	30	19,200		
		31	19,600		

TABLE 5: CLIMATIC CONDITIONS - WHITEHORSE - MEANS FOR THE PERIOD 1941 - 1970.

Month	Temperature (°C)			Precipitation (cm)			Bright Sunshine hrs./mo.	Wind Direction	Speed (Km/h.)
	Max.	Min.	Mean	Snow	Rain	Total			
Jan.	-14.7	-23.1	-18.9	20.6	0	1.85	42	S	11.9
Feb.	- 8.4	-17.9	-13.2	15	0	1.41	81	S	14
Mar.	- 2.1	-13.3	- 7.7	16.6	0	1.46	160	SSE	10
Apr.	5.1	- 5.3	- 0.1	10.6	0.5	1.07	230	SSE	12.8
May	13.1	1.1	7.1	2.4	1.07	1.35	267	SSE	8.4
June	19.3	5.9	12.4	0.5	2.85	2.86	271	SSE	9.1
July	20.1	7.1	14.1	0	3.33	3.33	250	SSE	7.6
Aug.	18.1	6.6	12.3	0	3.57	3.57	225	SSE	8
Sept.	12.5	3.0	7.8	3.9	2.51	3.0	134	SSE	11.5
Oct.	4.3	- 3.0	0.7	13.7	0.66	1.99	96	SSE	16.7
Nov.	- 5.1	-12.4	- 9.0	23.1	0	2.25	48	S	8.9
Dec.	-11.9	-19.7	-15.8	20.8	0	1.96	21	NNW	7.4
ANNUAL MEAN OR TOTAL	4.2	-5.9	-0.9	127.2	140.4	261	1,825		10.5

TABLE 6: WATER QUALITY - YUKON RIVER 1977

Whitehorse Rapids Spillway (mean values recorded Jun.-Dec. 1977)

Total Phosphates mg/l	Nitrites/Nitrates mg/l	Total Dissolved Nitrogen mg/l	SiO ₂ mg/l	Total Inorganic Carbon mg/l	Total Organic Carbon mg/l
0.017	0.014	0.090	3.109	10.028	1.781

Whitehorse Rapids Raceway (mean values recorded Jun.-Dec. 1977).

Total P (mg/l)	N/N (mg/l)	Total Diss.N (mg/l)	SiO ₂ (mg/l)	TIC (mg/l)	TOC (mg/l)
0.011	0.026	0.117	3.196	10.015	2.210

Lewes Dam (mean values recorded Jun.-Dec. 1977).

Total P (mg/l)	N/N (mg/l)	Total Diss.N (mg/l)	SiO ₂ (mg/l)	TIC (mg/l)	TOC (mg/l)
0.011	0.007	0.081	3.112	10.000	1.845

Whitehorse Rapids Dam (mean monthly values recorded, 1977).

	Water Temp. °C.	pH	Conductance µmho/cm.	Colour rel.units	Turbidity JTU	T.D.S. mg/l	Hardness CaCO ₃ mg/l	Calcium mg/l	Magnesium mg/l
Jun.	13.1	7.9	107	10	3.3	58	48	16.3	1.7
Jul.	15.4	8.2	94	5	0.9	53	44.3	15	1.7
Aug.	17.1	8.1	91	5	0.8	50	42	14.1	1.7
Oct.	7.5	8.4	95	5	0.5	53	43.8	14.9	1.7
Nov.	ice	8.8	88	5	1.2	56	47	15.2	2.3
Dec.	ice	9.1	120	5	1.1	57	47.4	16.2	1.7

	Potassium mg/l	Sodium mg/l	Silica mg/l	Total Alkalinity CaCO ₃ mg/l	Bicarbonates HCO ₃ mg/l	Chloride mg/l	Fluoride mg/l	N.F.R. mg/l	F.R. mg/l
Jun.	1.0	1.2	3.6	45.3	55.4	0.5	0.09		
Jul.	0.8	1.2	3.2	41.8	51	0.3	0.11	2	93
Aug.	0.6	1.0	3.0	37.9	47	0.4	0.09		
Oct.	0.7	1.1	3.1	41.1	50	0.3	0.09		
Nov.	0.8	1.2	3.4	44.3	54	0.3	0.1		
Dec.	0.8	1.1	3.4	45	55	0.2			

Water temperatures at Whitehorse Rapids Dam during the chinook salmon spawning migration (late July to early September) varied between about 15 and 17°C. Temperatures in this range have been cited by Brett et al. (1958) and Brett and Glass, 1973 as representing those required for optimum swimming performance of some species of Pacific salmon.

The pH of the river water ranged between 7.9 and 9.1 units and conductivity varied between 88 and 120 µmho/cm. Total dissolved solids averaged between 50 and 58 mg/l indicating potentially low standing crops of aquatic organisms (Larkin and Northcote, 1958).

Amount of residue and turbidity in the Yukon River at Whitehorse was low. Average values for non-filterable residue and filterable residue were 2 and 93 mg/l respectively while turbidity varied between 0.5 J.T.U. in October and 3.3 J.T.U. in June.

Water hardness varied between 42 and 48 mg of CaCO₃/l during the 1977 sampling period indicating that the water could be classified as soft (containing less than 50 mg/l of CaCO₃). Total alkalinity and bicarbonate values varied between 37.9 and 45.3 and 47 and 55.4 mg/l respectively.

The concentration range of dissolved cations was: sodium 1-1.2 mg/l; potassium 0.6-1.0 mg/l; magnesium 1.7-2.3 mg/l and calcium 14.1-16.3 mg/l. Anion concentrations were: chloride 0.2-0.5 mg/l; fluoride 0.09-0.11 and silica 3.0-3.6 mg/l.

Total dissolved nitrogen values varied between 0.081 mg/l at the Lewes Dam and 0.026 mg/l at Whitehorse Rapids raceway. Nitrites/nitrates varied between 0.007 and 0.026 mg/l respectively at the above sites.

Total phosphorus values were also very low, averaging between 0.011 and 0.017 mg/l.

Total organic carbon and total inorganic carbon concentrations (mean values 1.945 and 10.014 mg/l respectively) measured in 1977 indicate minimal amounts of organic or inorganic wastes were present in Yukon River water at Whitehorse Rapids Dam.

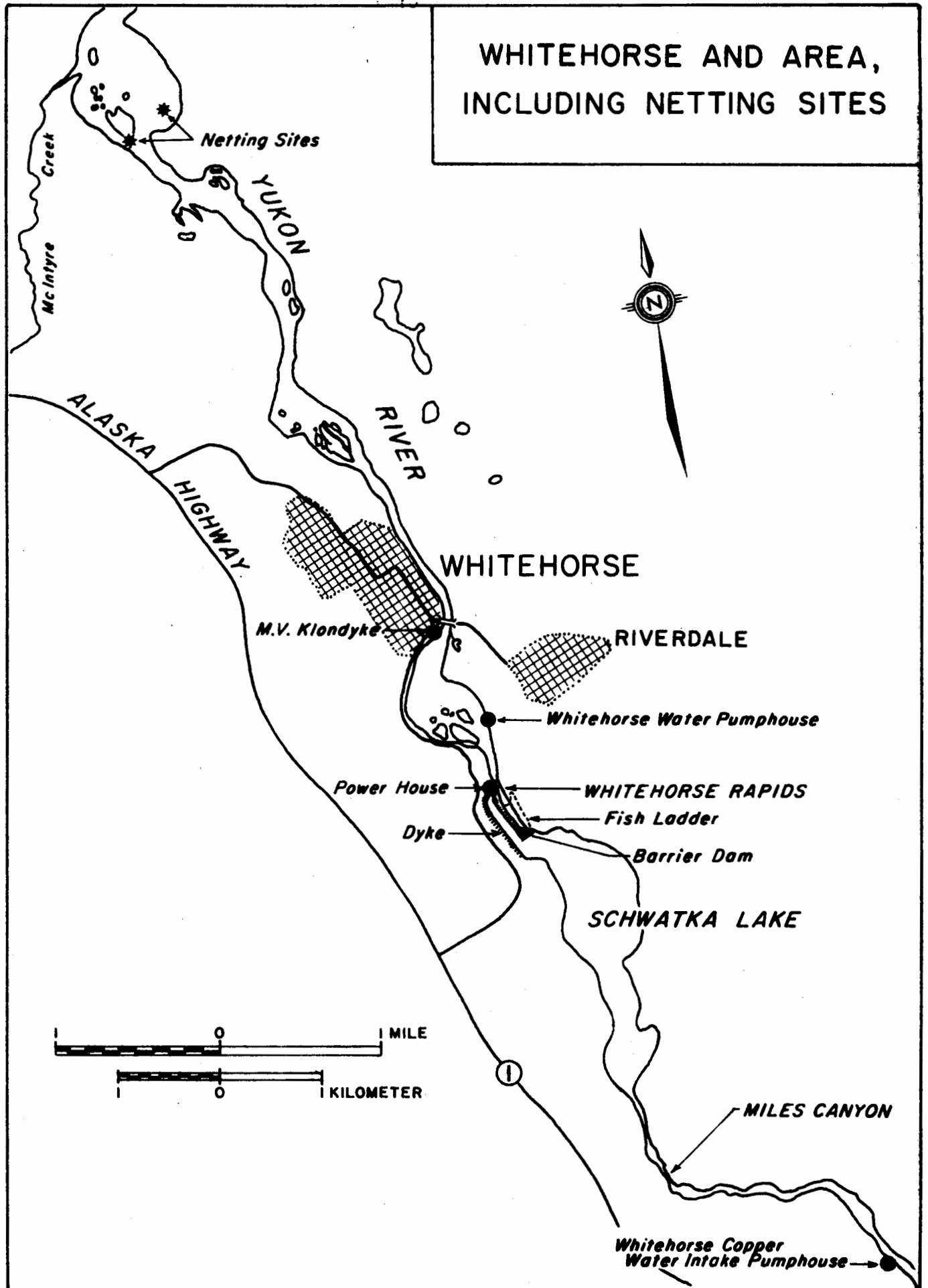
3. METHODS

During the 1979 chinook salmon migration (1-30 August), adult salmon were trapped, tagged and released at several locations in the vicinity of Whitehorse Rapids Dam. Fish were caught and tagged at two locations: McIntyre Creek and the Whitehorse Rapids Fishway (Figure 3). Initially, salmon were captured (August 1-10) using tangle nets at McIntyre Creek. Three nets (164 m x 16.5 cm x 19 cm mesh) were fished 24 hour/day for 10 days at this location. Only three fish were tagged at this site, however. Several other salmon caught in the tangle nets were either dead or too badly damaged to tag. Fish tagged at this location were held for 4 to 12 hours prior to release in pens (1.3 m x 1.3 m x 1.3 m) constructed of 1 cm stretched nylon mesh on a 5 cm polyethylene pipe frame.

Eighteen adult chinook salmon were tagged in the Whitehorse Rapids Fishway. Fish were dip-netted from the viewing box, tagged and either released at the City of Whitehorse water pumphouse (7 fish), below the fishway (2 fish), within the fishway itself (3 fish) or directly into the reservoir (6 fish; in order that an estimate of migration time through the reservoir could be made). Fish were transported in a small tank on the back of a truck. Transport time was less than one minute.

Tagging was accomplished by pushing the radio tag (coated with dental acrylic plastic) into the anterior of the fish's stomach

WHITEHORSE AND AREA,
INCLUDING NETTING SITES

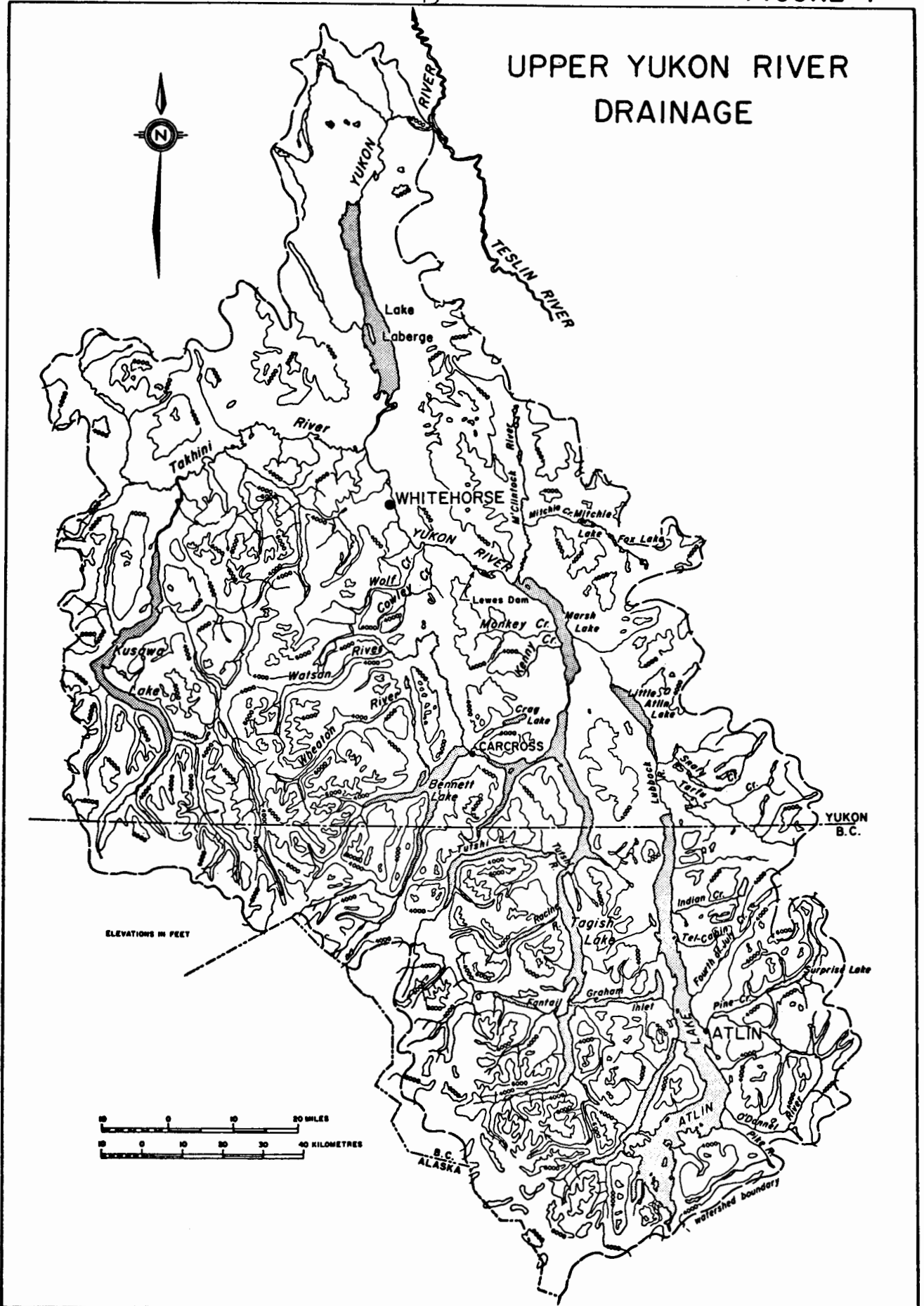


or the lower esophagus (see Appendix 1) with a smooth, plastic knitting needle while the fish was held firmly in a tagging trough. No anaesthetics were used. A Petersen Disc tag was also attached to assist visual identification of tagged fish at the Whitehorse Rapids counting chamber.

After tagging and transportation, fish movements were monitored between 0700 and 2200 hours daily, using three portable telemetry receivers located in boats, trucks or helicopters. Monitoring was also continuous at the viewing box during fishway counting operations (0700 to 2200 hours) from August 1 to September 4.

One telemetry receiver continuously monitored tagged fish movements at the damsite, the second receiver monitored movements upstream from Schwatka Reservoir to the spawning sites and the third receiver monitored movements upstream from the release site to the dam or downriver (dropback). The dropback fish movements were monitored to Lake Laberge and up the Takini River to Kusawa Lake (Figure 4). The frequency of monitoring for tagged fish was as follows (see Figures 2, 3 and 4):

1. Continuous observations at the Whitehorse Rapids Fishway viewing box between August 1 to 31, 0700 to 2200 hours.
2. Monitor for tags at damsite 6 to 12 times each day, August 1-30.
3. Spot check for tagged fish 3 times per day, August 1-20 at the following sites: M.V. Klondike, Whitehorse City pumphouse, at the northern boundary of the City of Whitehorse, and at Miles Canyon.
4. Two trips by boat, from Schwatka Reservoir to the Lewes Dam between August 2-16.



5. Several trips (2-6) per day between McIntyre Creek to Whitehorse townsite, August 1-10.
6. Several trips (6) using boat and truck, to Lake Laberge and Takini River (to Kusawa Lake) between August 10-18 to check for fish dropback movements.
7. Two boat trips from the Lewes Dam up to McClintock River to approximately Mile 5, August 12 and 16.
8. Spot checks at road access points to the river, above and below the dam, August 6-18.
9. Three helicopter trips (total 10 hours) to check for radio tags on potential spawning gravels or to follow migrating fish movements, August 22, September 2 and 3.

The helicopter survey (number 9 above) consisted of flights over all known or potential stream spawning grounds. Since Michie Creek was the only known spawning area it was surveyed twice; the remaining streams were surveyed once. The streams surveyed (see Figure 4) in order of observation were:

1. Yukon River - Whitehorse to Marsh Lake
2. Wolf and Cowley Creeks
3. Michie Creek and McClintock River
4. Tagish River
5. Lubbock River and Tarfu and Snafu Creeks
6. Indian, Tel-Cabin, Fourth of July, Pine Creek (Surprise Lake), and O'Donnel and Pike Rivers
7. Atlin River
8. Fantail River
9. Racine Creek
10. Tutshi River
11. Wheaton River
12. Watson River
13. Crag Lake
14. Kenney and Monkey Creeks

In order to assess fish migration through the transportation channel (bypass) at the Whitehorse Rapids powerhouse, a 6" mesh gill-net was installed across the entire channel on August 3-5. The net was fished continually for one 24 hour period and several shorter intervals of 2 hours each. In addition, on-site visual inspections of the channel were carried out for 30 additional hours during the peak of the migration period (August 3-15).

4. RESULTS AND DISCUSSION

4.1 Enumeration of Chinook Salmon at Whitehorse Rapids Fishway

The chinook salmon study at Whitehorse Rapids included enumeration of total escapement at the fishway, as well as radio-telemetry tagging to determine actual delays and migration behaviour of salmon at the facilities. The total escapement for 1979 was 1,184 chinook salmon. The first salmon was sighted in the fishway on 1 August, and the run terminated on 30 August 1979. The peak of the migration occurred between August 3 and 15; by August 16, 1,000 fish had passed through the fishway.

4.2 Transportation Channel Tests

Net test fishing in the transportation channel yielded no fish in three days of fishing. On-site observations failed to record any fish migration through the bypass over the study period (Aug. 3-15). Salmon utilized the upper transportation channel throughout the migration period as a back eddy rest area prior to entering the fishway. No fish were observed in the lower three control structures of the transportation (bypass) channel.

4.3 Pattern of Migration

A brief account of the individual movements of tagged fish is given in Table 7 and Appendix II. An illustration of the movements of fish with tags 14789 and 14792 is given in Figures 5 and 6.

TABLE 7: BRIEF ACCOUNTING OF TAGGED FISH MOVEMENTS

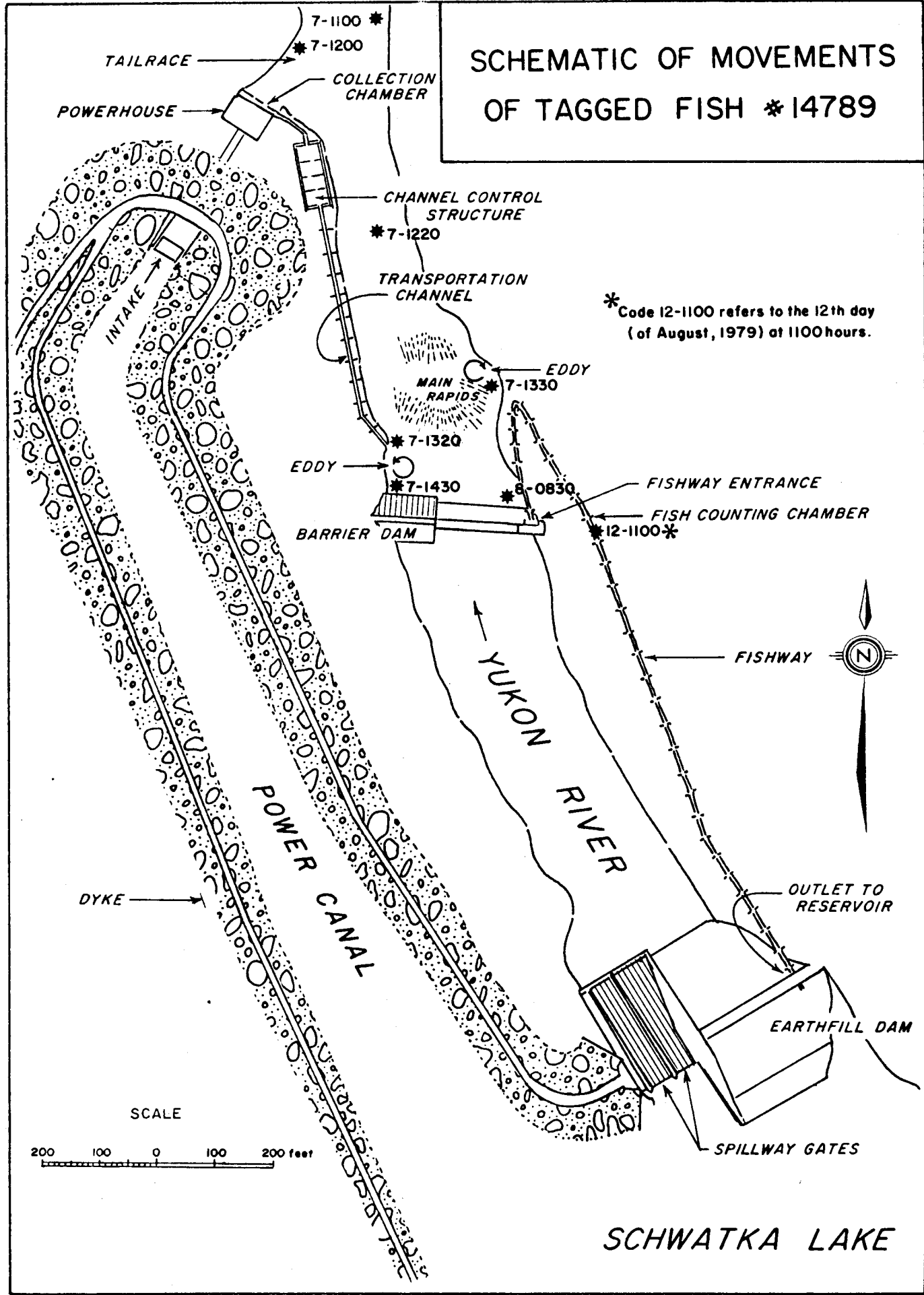
Tag	McIntyre	Townsite	Water Pumphouse	Fishway	Bypass	Viewing Box	Reservoir	Whitehorse Copper Pumphouse	Lewes	Spawning Ground	Comment
14780 1			2012 3 Aug.	1530 8 Aug. +	1450 10 Aug.						1450 10 Aug. lost contact did not go through fishway
14782 2			V O I D T H I S T A G								Tag malfunction
14784 3				0800 5 Aug. +	0840 5 Aug. +	1300 10 Aug.	1330 10 Aug.	0900 11 Aug.		Marsh Lake near Monkey Creek	
14787 4		1000 8 Aug.	2032 3 Aug.								Located 10 Aug. at MV Klondike, lost contact 11 Aug.
14788 5						2010 4 Aug.	0930 14 Aug.			Michie 3 Sept.	Lost contact.
14791 6			1930 6 Aug.	0910 7 Aug. +	1445 8 Aug.						Lost contact below dam 1445 8 Aug.
14793 7	1300 2 Aug.			1100 3 Aug. +	1600 3 Aug. +	0920 5 Aug.	1145 5 Aug.		1000 8 Aug.	2 Sept. Michie Cr.	
14795 8	1830 2 Aug.			1325 3 Aug. +	1430 3 Aug. +	1945 5 Aug.	2030 5 Aug.			2 Sept. Surprise Cr.	
14796 9						1930 2 Aug.	2030 2 Aug.			2 Sept. Michie	
14799 10	1330 1 Aug.	0830 2 Aug.	1300 3 Aug.	1000 4 Aug.							Could not locate below dam after 1445 8 Aug.
14800 11				2000 1 Aug. +	1100 3 Aug.						Could not locate 5 Aug. 0845, lost downstream.
14803 12						1935 2 Aug.	0730 3 Aug.		1000 7 Aug.	2 Sept. Michie	

TABLE 7: (cont'd.)

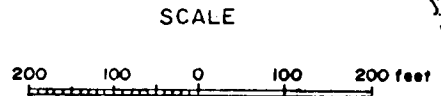
Tag	McIntyre	Townsite	Water Pumphouse	Fishway	Bypass	Viewing Box	Reservoir	Upper River	Lewes	Spawning Ground	Comment
14781 1							0900 6 Aug.			2 Sept. Michie Cr.	
14783 2							0900 6 Aug.			2 Sept. Michie Cr.	
14785 3							0905 6 Aug.			3 Sept. Michie Cr.	
14786 4							0920 6 Aug.			2 Sept. Michie Cr.	
14789 5*			0800 7 Aug.	1330 ← 7 Aug.	→ 1430 7 Aug.	1600 12 Aug.	0930 14 Aug.				Could not locate on spawning grounds.
14790 6			0800 7 Aug.	0830 8 Aug.		1945 8 Aug.				3 Sept. Michie Cr.	
14792 7			0830 7 Aug.	1930 7 Aug.		1500 16 Aug.				3 Sept. Fox Lake	Located in river just below entrance to Fox Lake.
14794 8			0840 7 Aug.	1030 ← 8 Aug.	→ 1430 8 Aug.	1000 11 Aug.	1100 12 Aug.			2 Sept. Michie Cr.	
14797 9			V O I D T H I S T A G								Tag malfunction.
14798 10							0900 9 Aug.			2 Sept. Michie Cr.	
14801 11							0900 9 Aug.	0930 10 Aug.		2 Sept. Michie Cr.	
14802 12			V O I D T H I S T A G								Tag malfunction.

← → represents several movements between the fishway and the bypass

SCHEMATIC OF MOVEMENTS OF TAGGED FISH *14789

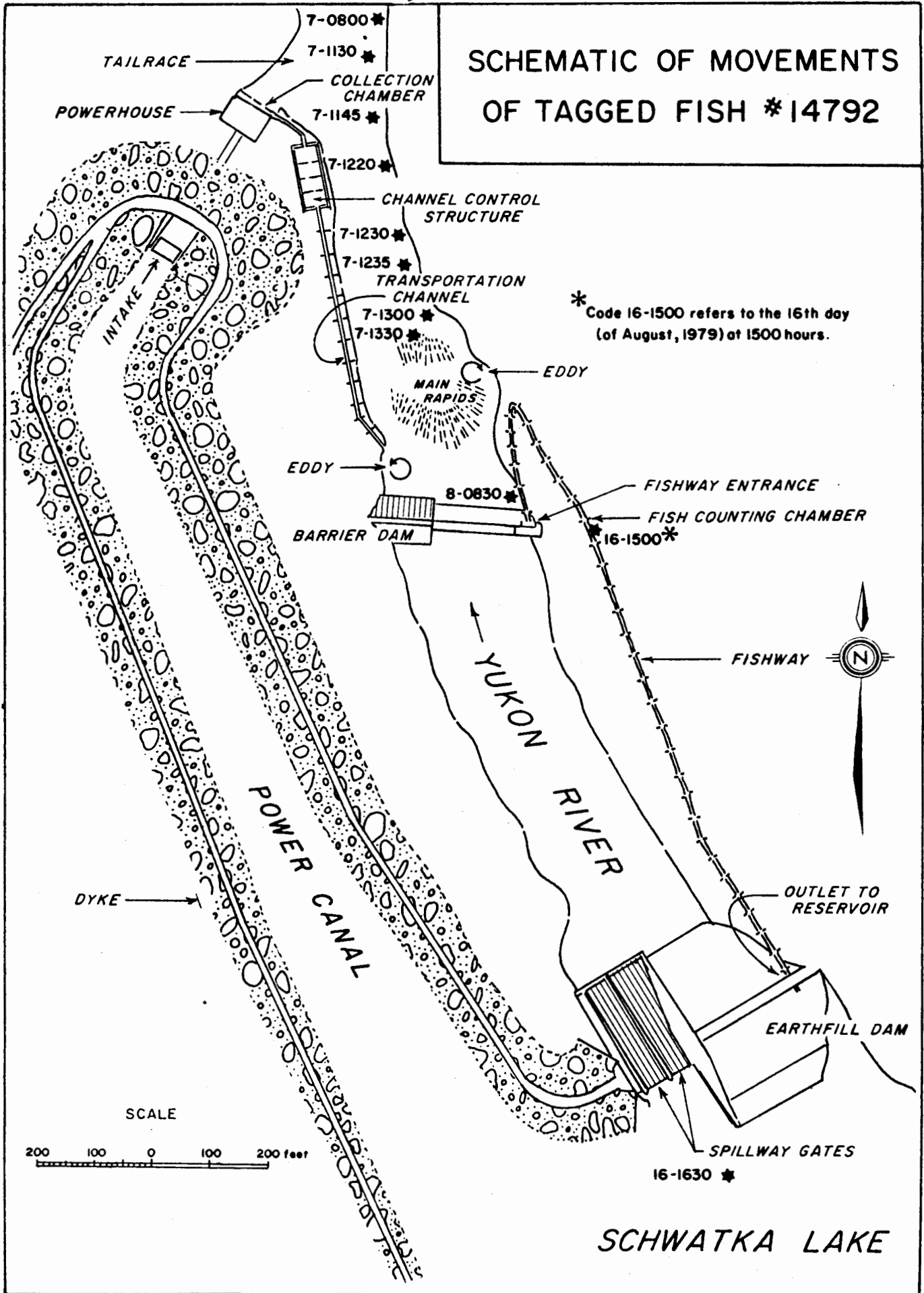


*Code 12-1100 refers to the 12th day (of August, 1979) at 1100 hours.



SCHWATKA LAKE

SCHEMATIC OF MOVEMENTS OF TAGGED FISH #14792



Between McIntyre Creek and the damsite the tagged fish showed no preferred pattern of migration. Tagged fish migrated on both sides of the river as well as midstream. Back eddies were frequented for varying lengths of time (1 hour to 4 days). Fish moved during both night and daylight hours. Migration time from McIntyre Creek to the damsite was 3 days for each of the two fish monitored. Between the City of Whitehorse water pumphouse and the damsite the migration time was about 2 hours for three fish and 28 hours for one fish.

In the area downstream of the damsite tagged fish moved freely between the area of the fishway entrance and the powerhouse. Both sides of the river were utilized and back eddies usually contained large numbers of holding fish. Tagged fish made frequent lateral movements in front of the barrier dam between the fishway entrance and the transportation channel back eddy. As well, no fish appeared to show any major time delay in migrating beyond the large rock outcrop at the fishway entrance.

The upper end of the transportation channel was frequently used as a holding area, and large number of fish (often in excess of 50) utilized this 'man-made' eddy. Tagged fish migrating through the fishway remained at the base of the barrier dam for a minimum of 10 hours to a maximum of 9 days, (with an average delay of 3 days), prior to entering the fishway. Migration time through the fishway varied from $\frac{1}{2}$ hour to 1 day; average time was 7 hours with the exception of 1 fish injured during the tagging operation which remained in the fishway for 7 days.

Tagged fish entering Schwatka Reservoir apparently migrated at great depth, in excess of 16 metres, since radio signals from these fish were very weak once the fish entered the reservoir. Migration timing through the reservoir to the Whitehorse Copper water intake

was 24 hours based on 3 monitored fish. Two tagged fish were monitored from Schwatka Reservoir to the Lewes Dam; one fish negotiated this 29-32 Km of river in 45 hours, a second fish took 68 hours.

It is notable that the salmon were tagged in the early 1/3 of the migration, between 1 and 9 August when they appeared in good physical condition. The physical condition of fish in the latter 2/3 of the migration was poor. These fish had frayed fins, cuts, bruises and usually some fungus infection. Accordingly, tagging results are biased towards fish in good condition negotiating the fishway. The observed delays then, must be considered conservative.

4.4 Spawning Areas

Of the 24 tags used in this survey, 3 malfunctioned, 5 were lost downstream of the Whitehorse Rapids Dam and 16 tagged fish passed through the fishway. Of the 16 tagged fish that passed over the dam, 15 were located on the spawning grounds and 1 fish could not be located. Thirteen fish were located in Michie Creek, 1 above Michie Lake at the outlet of Fox Lake, and 12 in Michie Creek immediately below Michie Lake. One fish was located in Marsh Lake at the outlet of Monkey Creek and another "probable" tagged fish was located in Pine Creek at Surprise Lake. This last tag, at Pine Creek, cannot be confirmed since only two short signals were received. This may have been a result of a machine malfunction or movement of the tagged fish beneath a log jam, dock or other structure which interfered with the radio signals.

4.5 Unaccounted Tags

Five tagged fish could not be located after tagging. These fish probably did not move through the fishway as they would have been identified by the Petersen Disc tags. It is also unlikely that they dropped back downriver after tagging since in most cases this dropback occurred immediately after tagging and these fish remained near the tagging or damsite for 3 to 8 days. A dropback

search was made to Lake Laberge and up the Takini River to Kusawa Lake but failed to confirm any tagged fish.

It is postulated that these fish may have dropped downstream to spawn in another tributary system; or that the insertion of the tag may have ruptured the body cavity, eventually killing the fish which were then swept into Lake Laberge; or simply that a tag malfunction occurred.

5. SUMMARY

Results of the radio-tracking studies at the Whitehorse Rapids hydroelectric facilities indicate that the facilities and/or the geography and hydrology of the Yukon River at the rapids resulted in some delay in the upstream migration of adult chinook salmon. Observations of the pattern of chinook salmon migration demonstrated that the fish utilized the entire area at the base of the barrier dam. The high velocities presented minimal problems to fish crossing through the rapids to the vicinity of the fishway. Back eddies were frequently used by large numbers of migrants on both sides of the river, and the large rock outcrops on the downstream side of the fishway apparently presented no major obstacle. The mean delay caused by the barrier dam was 3 days. The fishway delayed the tagged fish an average of 7 hours. The majority of tagged fish passing through the fishway were located on the Michie Creek spawning grounds in early September.

Observations of migrating salmon indicated that the fish were not attracted into the powerhouse transportation chamber or the tailrace area. A determined effort to net fish using this bypass had negative results although some fish migrated along the powerhouse side of the river.

ACKNOWLEDGEMENTS

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W. Schouwenburg, R.A. Robertson, R. Higgins and G.T. Kosakoski critically reviewed this manuscript.

W. Field prepared the figures, and T. Collins typed and proofread this report.

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APPENDIX I
DESCRIPTION OF RADIO-TELEMETRY EQUIPMENT
USED FOR WHITEHORSE RAPIDS STUDY
AUGUST, 1979

The radio-telemetry equipment was developed by AVM Instrument Co., Champaign, Illinois, U.S.A. Each transmitter (fish module tag) 49.300 - 49.575 MHz was individually identifiable on a frequency of 49 MHz and had an effective life of 6 months. The tags weighed 11 grams and had external dimensions of 6.1 cm x 2.5 cm x 1 cm. Transmitter range varied according to the depth tags were submerged and orientation of the antenna (hand-held M-yagi) used to receive radio signals (Table I). Twenty-four tags were utilized; the channels and frequencies of each tag are listed in Table II).

Three portable receivers (AVM Model LA 12) were used to detect transmissions from individual tags. Each receiver had twelve channels with two tag frequencies being received on each channel (Table II).

A probe for tag emplacement was developed on-site and consisted of 2 large plastic knitting needles, one inserted inside the other. The larger hollow needle was notched-pointed at the end to hold the transmitter. The probe and tag were inserted into the fish's mouth and the smaller needle was pushed forward releasing the tag (Figure 1). Both needles were then withdrawn. External Petersen Disc tags were also attached to the fish to assist visual identification as the fish passed the viewing chamber.

Limitations of the radio-telemetry equipment used in this study were obvious from the initial tests. The receivers were not consistent in their ability to distinguish individual tag signals as noted in Table III. Receiver 960, for example, would receive tag 14798 on Channel 10, frequency 2.5, whereas receiver 959 would receive this same tag on either Channel 10, frequency 1 or Channel 9, frequency 5. This was somewhat confusing since receiver 972 would receive tag 14797

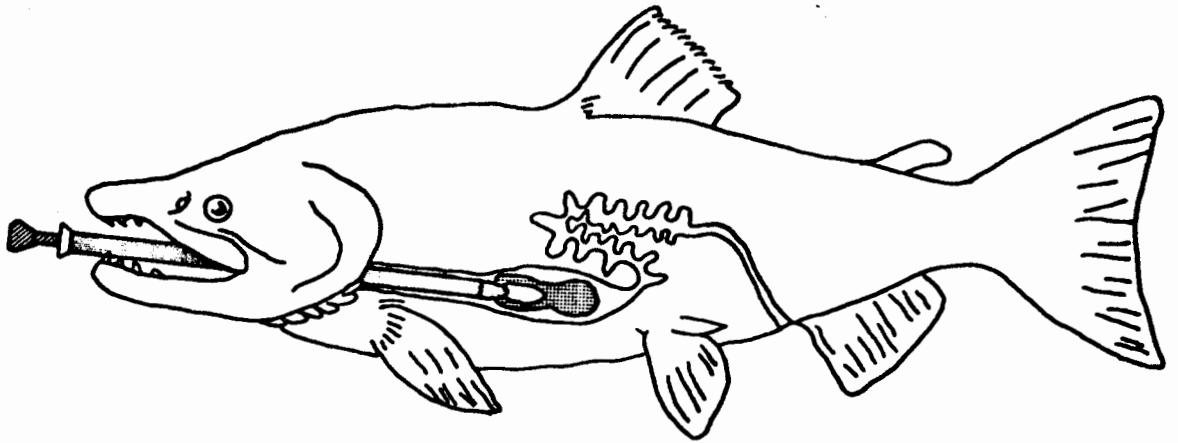
TABLE 1: TRANSMITTER RANGE EVALUATION CHANNEL 2,
GAIN 4.5 (TAG #14782) ANTENNA AT 45° ANGLE

<u>Depth(m)</u>	<u>Faint Detection(m)*</u>	<u>Clear Detection(m)*</u>
18	35	8
10	100	25
5	200	100
2	300	250

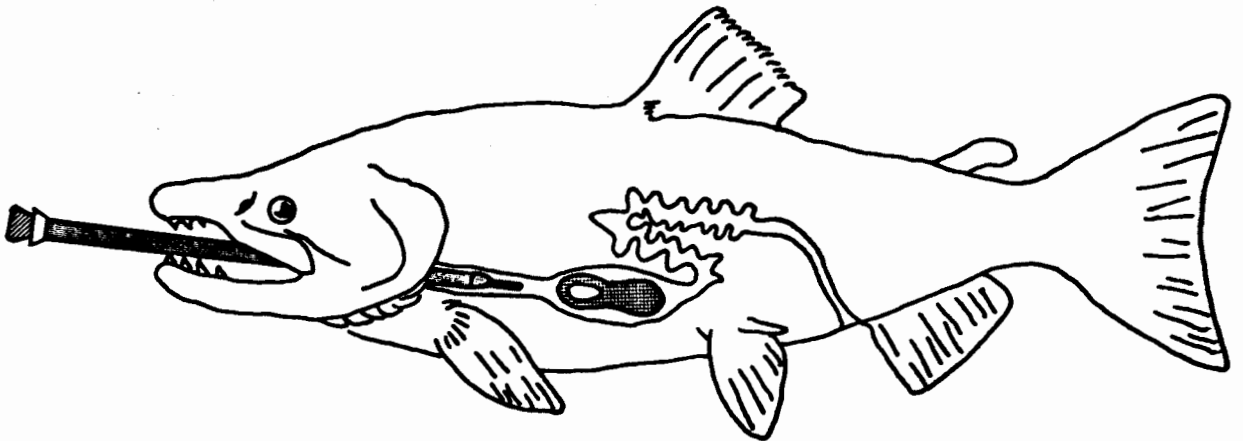
* horizontal distance from surface marker buoy attached to submerged tag to sonic receiver

TABLE II: LIST OF TRANSMITTERS (TAGS) WITH THEIR INDIVIDUAL CHANNELS AND FREQUENCIES

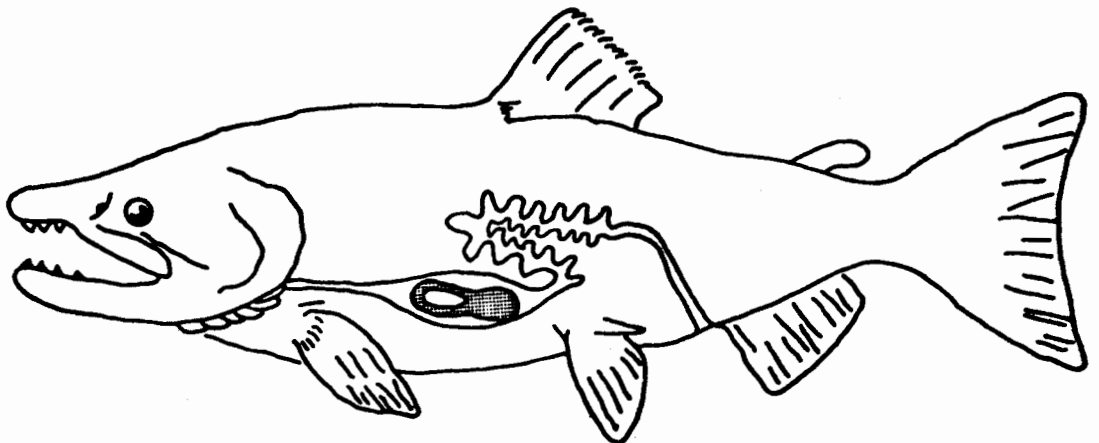
Channel	Channel Frequency (MHZ)	Tag #	Tag Frequency	Tag #	Tag Frequency
1	49.300	14780	3	14781	4.5
2	49.325	14782	2	14783	3
3	49.350	14784	2	14785	4
4	49.375	14786	1.5	14787	2.5
5	49.400	14788	2	14789	4
6	49.425	14790	3	14791	4
7	49.450	14792	1.5	14793	2.5
8	49.475	14795	2.5	14795	3.5
9	49.500	14796	1.5	14797	3.5
10	49.525	14798	2.5	14799	5
11	49.550	14800	0.5	14801	3
12	49.575	14802	1	14803	2.5



A. Sonic tag is placed in the anterior of stomach.



B. Sonic tag is released and injector withdrawn.



C. Sonic tag in place.

TABLE III: EXAMPLES OF INCONSISTENT TRANSMITTER FREQUENCIES FOUND DURING RADIO-TELEMETRY STUDIES

Tag (Transmitter)	R e c e i v e r s					
	960 Chan. Freq.		959 Chan. Freq.		972 Chan. Freq.	
14782	1	5	2	0.5	2	2.5
	2	2.5	1	5		
					or	
147801	11	2.5	11	2	11	3.5
					12	0.5
					or	
14798	10	2.5	10	1	10	3.5
			9	5		
					or	
14797	9	3.5	9	2.5	9	5
					10	1
					or	
14802	12	2	12	1.5	12	2.5
			11	5		
					or	

on Channel 9, frequency 5 as well. Differences in reception were noted and separate tracking records were kept for each receiver by each study team throughout the program. In addition, each tag frequency was tested with each receiver before tags were inserted in to the fish. Reduction in clarity of tag transmissions resulted if the fish (and tag) were located behind logs, rocks or concrete dam structures, or if the fish were in deep (>16 metre) reservoir water.

The hand-held M-yagi antennae were omni-directional and when used singly could only indicate the approximate position of tagged fish. In order to locate the position of fish more precisely, two or three M-yagi antennae and a modified television antenna were used.

Transmitters with frequencies located on the same channels were often difficult to separate. For example, tags 14782 and 14783 on Channel 2 were only 1 frequency interval apart (Table II); since there was some overlap of transmission this was often confusing when two fish on the same channel were in the same area. Another problem with the transmitters was an apparent shift in frequency of individual tags. The frequency change occurred on 13 of the 24 transmitters. With daily observations these changes did not affect the study results since the changes in frequency were continually updated in the log books. Three tags, however, were considered too erratic in their transmission outputs to be used in the study.

APPENDIX II
MOVEMENTS OF TAGGED FISH
AT
WHITEHORSE RAPIDS, 1979

Tag #	Channel/ Sex	
14799	10 ♂	- Tagged 1 Aug. at McIntyre Creek, moved to dam by 4 Aug. - could not locate after 8 Aug. - did not go through fishway.
14800	11 ♀	- Tagged in fishway 1 Aug. but slipped back to entrance, moved back and forth with relative ease between fishway and bypass; could not be located after 5 Aug. 0845 hrs.
14793	7 ♂	- Tagged 2 Aug. at McIntyre Creek, located at fishway entrance (or 6 miles in 22 hrs. or 0.27 miles/hr.), travelled between fishway and bypass with ease in less than 2 min. each way, passed through fishway on 5 Aug. - located at Lewes on 8 Aug. (20 miles in 70 hrs. or 0.29 miles/hr.). Located on spawning grounds (Michie Creek) on 2 Sept.
14795	8 ♀	- Tagged 2 Aug. at McIntyre Creek - escaped from holding pen overnight, located at fishway on 3 Aug. - passed back and forth to bypass and fishway with ease, through fishway on 5 Aug. - possibly* located at Pine Creek (Surprise Lake). *There may be some doubt here since only two sonic impulses were received, this could be due to: 1. malfunction of receiver, or 2. fish moved behind debris. Unfortunately we did not stop to locate fish.
14796	9 ♂	- Tagged in the fishway 2 Aug. and released above the viewing chamber, located 2 Sept. at Michie Creek.
14803	12 ♀	- Tagged in fishway 2 Aug. - released above viewing chamber, located at Lewes 7 Aug. and at Michie Creek on 2 Sept.
14780	1 ♂	- Tagged in fishway 3 Aug. and released at the pumphouse site. Located at fishway on 8 Aug., could not locate after Aug. 10., did not go through fishway.
14787	4 ♀	- Tagged in fishway 3 Aug. - released at pumphouse site dropped back to townsite by 9 Aug., 10 Aug. moved to MV Klondike, lost contact 11 Aug.

Tag #	Channel/ Sex	
14788	5 ♀	- Tagged in fishway 4 Aug. and released above viewing box, located in Michie Creek on 3 Sept.
14784	3 ♂	- Tagged in fishway 4 Aug., released in back eddy below fishway, moved between bypass and fishway until 10 Aug., 1200 hrs., moved through fishway between 1300 - 1330 hrs. on 10 Aug., 11 Aug. located at Whitehorse Copper water intake, 2 Sept. located in Marsh Lake near Monkey Creek.
14791	6 ♂	- Tagged in fishway 6 Aug., released in pumphouse eddy, returned to dam 7 Aug., stayed below fishway entrance until 8 Aug., lost contact, did not go through the fishway.
14781	1 ♂	- Tagged in fishway 6 Aug., released in reservoir, located Michie Creek 2 Sept.
14783	2 ♀	- Tagged in fishway 6 Aug., released in reservoir, located Michie Creek 2 Sept.
14785	3 ♂	- Tagged in fishway 6 Aug., released in reservoir, located Michie Creek 3 Sept.
14786	4 ♂	- Tagged in fishway 6 Aug., released in reservoir, located Michie Creek 2 Sept.
14789	5 ♂	- Tagged in fishway 0800 hrs. 7 Aug., released in pumphouse eddy at 1100 hrs., followed up river to dam 1100 to 1330 hrs., this fish travelled up the west (powerhouse) side of the river towards the dam, at the powerhouse (turbines) the fish moved along the outside (in the river) edge of the bypass, crossed over the mid-river at the upper end (south) of the bypass towards the fishway and remained in the eddy at the entrance of the fishway until 11 Aug. Passed through the fishway on 12 Aug. This fish could not be located on the spawning grounds.
14790	6 ♂	- Tagged 0800 hrs., 7 Aug. in fishway, released in pumphouse eddy, 1100 - 1300 hrs. fish moved up the fishway side of the river (east side). Located at fishway entrance 1200 hrs. 8 Aug., by 1945 fish passed through fishway. Located 3 Sept. in Michie Creek.

Tag #	Channel/ Sex	
14792	7 ♂	- Tagged in fishway 7 Aug., released in pumphouse eddy 0830 hrs., 1100-1300 fish moved from release site up the fishway side of river, 1330 located in midstream; 0830 hrs., 8 Aug. at fishway entrance remained there until 16 Aug. 1500 when fish passed through fishway, located 3 Sept. at outlet of Fox Lake.
14794	8 ♀	- Tagged in fishway 7 Aug., released at pumphouse eddy 0840, 8 Aug. 0830 located at bypass, 1030 moved to fishway eddy, 11 Aug. 1000 in fishway, 1330 in reservoir, 2 Sept. located at Michie Creek.
14798	10 ♂	- Tagged in fishway 9 Aug. to follow through reservoir, immediately went very deep 16+ metres, lost 1-2000 metres from release point, located in Michie Creek 2 Sept.
14801	11 ♀	- Tagged in fishway 9 Aug., released in reservoir 0930 hrs., located at Whitehorse Copper water intake 0930 10 Aug., 1445 10 Aug. fish moved 3 miles upriver, 1545 located at S Bend, 0900 12 Aug. located at Lewes, 2 Sept. located in Michie Creek.