FRED Reports

CHANDALAK-CHRISTIAN RIVERS AREA FISHERIES
REHABILITATION AND ENHANCEMENT STUDY

by

Robert F. McLean

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J.A. Raymond

Number 13

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
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ABSTRACT

Broad whitefish (Coregonus nasus), humpback whitefish (Coregonus pidschian), grayling (Thymallus arcticus), chum salmon (Oncorhynchus keta) and northern pike (Esox lucius) are the fish species most heavily used by subsistence and sport fishermen in the Chandalar-Christian Rivers area (CCR), although the effort in both fisheries is low. The major chum salmon spawning areas are presently in the main Chandalar River near and below Venetie but in the past included the East Fork.

Broad, humpback and round whitefish (Prosopium cylindraceum) generally grow more slowly in the CCR than they do in other parts of Interior Alaska, possibly because of low food availability. In the East Fork of the Chandalar, broad whitefish may spawn in alternate years; they may spend the winter before spawning in Loon Lake and the winter after spawning in the Chandalar River. Venetie Lake near Venetie was found to contain hydrogen sulfide and low levels of oxygen in March. The lake was once an important summer feeding area for broad whitefish but now appears to be isolated from the stream system. The isolation may be due to lower water levels, but man-made dams near the inlet and outlet of the lake may be partly responsible.

Whitefish habitat in the CCR may be declining. Weather records and aerial photographs were found to be consistent with claims by Natives that lake levels had declined in the past 30 years.

A search for water sources that would be suitable for a conventional salmon hatchery was unsuccessful. Methods for incubating fall chum and chinook (O. tshawytscha) salmon are suggested, but questions on low water temperatures, low food availability and poor water quality in the CCR need to be answered before hatchery production of salmon or whitefish can be considered. Presently, the most useful fisheries enhancement project appears to be whitefish habitat improvement, specifically at Venetie Lake and Loon Lake. Natives in the CCR appeared to favor rehabilitation of whitefish and enhancement of chinook salmon to improve their subsistence fisheries. They were not interested in developing a commercial fishery.

KEYWORDS: fish culture, fisheries rehabilitation and enhancement, fish resources, life history, Oncorhynchus tshawytscha, chinook salmon, Oncorhynchus keta, chum salmon, Coregonus nasus, broad whitefish, Coregonus pidschian, humpback whitefish, Prosopium cylindraceum, round whitefish, Chandalar River, Christian River, Venetie Lake, Loon Lake, Shovun Lake, Twentymile Lake, Venetie, Arctic Village.

INTRODUCTION

The Division of Fisheries Rehabilitation, Enhancement and Development (FRED) of the Alaska Department of Fish and Game (ADF&G) was asked by the 1981 Alaska Legislature to identify the fish resources of the Chandalar and Christian Rivers area (CCR) and to evaluate the potential for fisheries rehabilitation and enhancement. The entire area (Fig. 1) is above the Arctic Circle, and most of it falls within the boundaries of the Venetie Indian Reservation. Venetie and Arctic Village are the only villages in the CCR. The mouths of the Chandalar and Christian Rivers are approximately 1540 km upstream from the mouth of the Yukon River.

Little is known about the fishery resources and their use in the CCR. The Department of Fish and Game has intermittently surveyed the fall chum salmon (*Oncorhynchus keta*) spawning run in the Chandalar River since 1974 and has estimated the subsistence salmon harvest in Venetie Village since 1962 (Geiger and Andersen 1980). The Department has also conducted test fishing in several lakes in the CCR (Roguski and Spetz 1968; Kramer 1976; and Pearse 1978). Pearse (1979) summarized these studies. Mills (1980, 1981) conducted surveys of sport fishing effort in a portion of the south slope of the Brooks Range which included the CCR. Surveys of fish distributions, stream invertebrate densities and hydrology were conducted by several investigators for the Canadian Arctic Gas Pipeline Company in the upper East Fork of the Chandalar River (McCart 1974; Craig and McCart 1974; Ward and Craig 1974; Craig and Wells 1975). Additional hydrologic data for this area were reported by Childres et al. (1973). A brief survey of fish resources and salmon enhancement potential at Venetie and Arctic Village was made by one of us (J.R.) in 1977. The results of that trip are included in this report. Caulfield (1983) has recently completed a study of subsistence land use in communities in the Upper Yukon-Porcupine area, including Arctic Village and Venetie.

We attempted to answer three questions in this study: (1) What are the major fish species in the CCR? (2) What factors are limiting the production of the most important of these species? and (3) What are the opportunities for fisheries rehabilitation and enhancement?

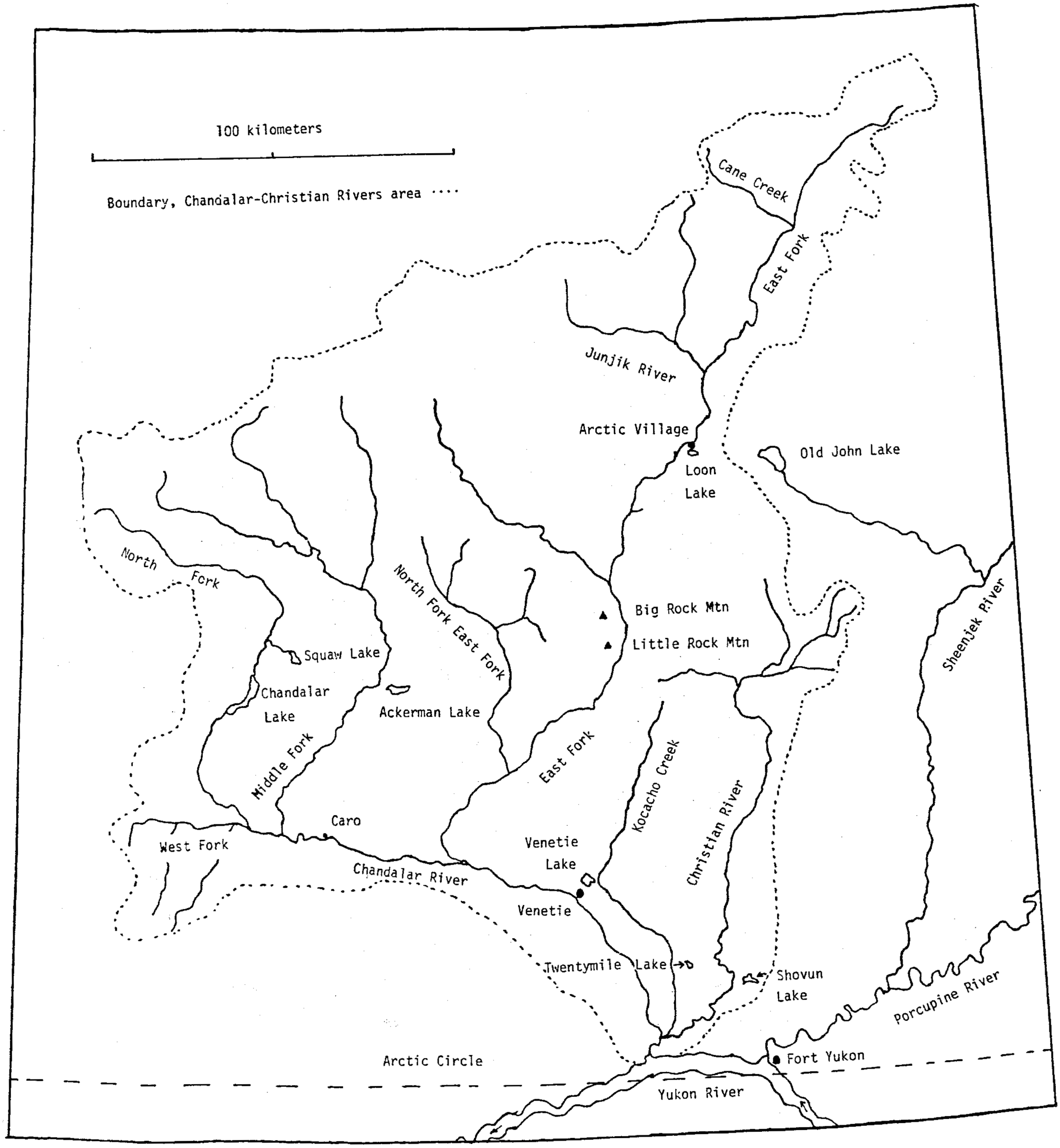

Figure 1. Map of the Chandalar-Christian Rivers area.

MATERIALS AND METHODS

Seven field surveys were conducted (Table 1). Data were collected through on-site investigations and interviews. We met with most local officials and other interested residents in Arctic Village and Venetie to discuss fisheries rehabilitation and enhancement.

Water temperatures were measured with a mercury thermometer with 0.1 °C divisions. Water flows were measured by estimating average width, depth and water velocity. Dissolved oxygen concentration was measured with a Model AL36B Hach field kit. Holes were drilled through ice using a Jiffy Model 20 gasoline-powered ice auger with a 20-cm (8-in.) bit.

A 40-m-long gill net containing five panels with meshes of 25, 50, 75, 100, and 125 mm (stretch), was used for winter test fishing. An additional 30-m-long variable mesh gill net containing two panels of 64- and 75-mm mesh was used during the Shovun Lake survey. The Shovun Lake nets were set with an inflatable Avon raft with a 15-hp motor, both loaned to us by the Commercial Fisheries Division. Broad whitefish (Coregonus nasus) that were examined near Arctic Village were collected by Peter Tritt with a 15.2-m-long, 62.5-mm-mesh gill net.

Broad whitefish were aged with scale samples taken from the left side midway between the posterior dorsal fin and anterior anal fin. Scales were cleaned and mounted on a gummed card, from which a plastic impression was made. Scale annuli were then read from the impression on a microprojector. Stomach contents of the broad whitefish were identified by Rae Baxter of the Commercial Fisheries Division.

Chum salmon fry were collected with a shovel from the spawning beds and preserved in 70% isopropyl alcohol. Lengths were measured from the tip of the snout to the fork of the tail. Weight was determined by averaging the total sample weight after blot drying.

We set gill nets under ice with a "jig pole" modified from Bendock (1980). The jig pole consisted of four 4.5 by 4.5 cm by 1.8 m-long poles bolted together at the ends so that they could rotate in only one plane (Fig. 2). Holes were drilled through the ice at roughly 5-m intervals. A rope was attached to the end of the jig pole and pushed from the first hole to the second where its leading end was retrieved with a hooked stick. This process was repeated until the rope had been strung under the ice to the last hole. The rope was then used to pull the gill net under the ice. The nets were adjusted to fish approximately 50 to 100 cm below the ice. Spruce boughs and powdered snow were placed on top of each hole to reduce the amount of freezing in the hole.

Table 1. Field surveys conducted in the Chandalar-Christian Rivers area.

Dates	Travelers	Locations
17-21 Aug 1977	J.R.	Fort Yukon, Venetie, Arctic Village
10-13 Nov 1981	R.M.	Fort Yukon
1- 2 Dec 1981	R.M.	Venetie
2- 5 Feb 1981	R.M.	Arctic Village
22-26 Mar 1982	R.M., J.R.	Venetie and Twentymile Lake
23 May 1982	J.R.	Venetie Lake and Kocacho Creek overflight
14-17 Jun 1982	R.M., J.R.	Shovun Lake

Zooplankton was sampled with a 20-cm-diameter, 243-micron-mesh net loaned by the Fisheries Cooperative Unit, University of Alaska. Zooplankters were identified by Terry Tobias of the FRED Limnology Lab, Soldotna.

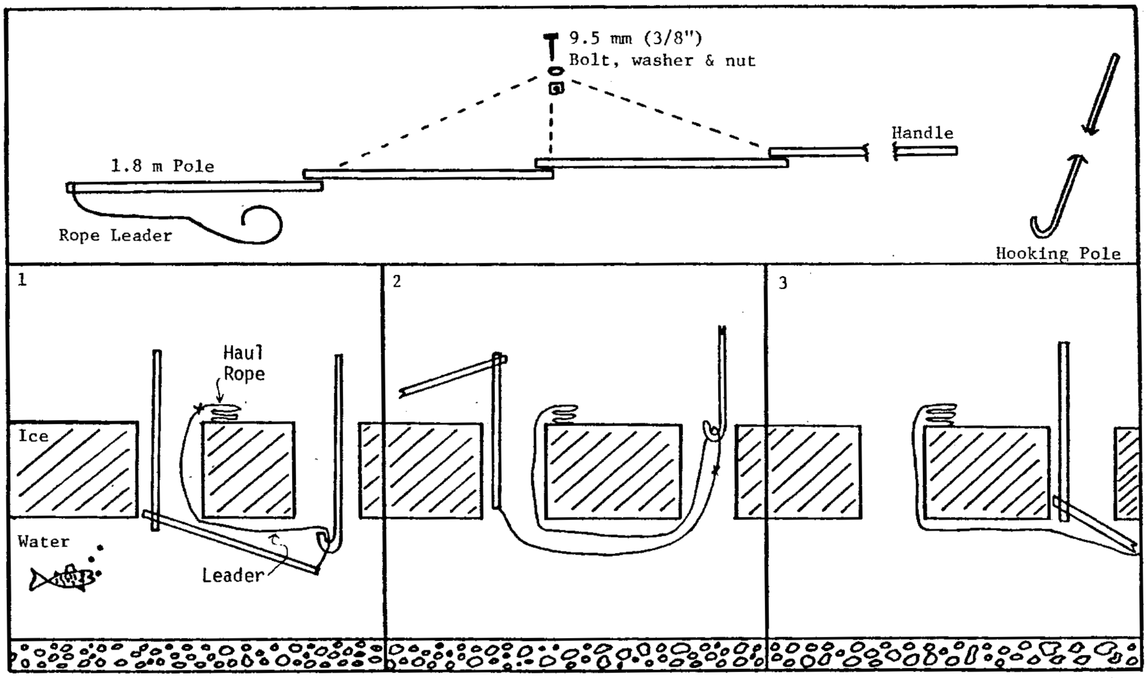

Figure 2. Method for setting a gill net under the ice (figure modified from Bendock (1980)). Construction of jig pole is shown at top. 1. Insert jig pole and maneuver rope leader to adjacent hole. 2. Hook rope leader with hooking pole, pull leader to surface, untie haul rope from leader and remove jig pole. 3. Rehook haul rope to leader and insert jig pole at next hole and repeat the procedure.

Drawing of a wood carving of a fish used as a grave marker in Arctic Village, probably made in the early 1900s. (Drawn from McKennan (1965), plate 26).

RESULTS AND DISCUSSION

Fish Resources and Their Use

Fifteen species of fish have been identified in the CCR (Table 2) (Craig and Wells 1975; Pearse 1978). The most abundant species are grayling (Thymallus arcticus), slimy sculpin (Cottus cognatus), round whitefish (Prosopium cylindraceum), northern pike (Esox lucius), long nose sucker (Catostomus catostomus), broad whitefish, humpback whitefish (Coregonus pidschian) and chum salmon. Fish are caught in the CCR chiefly for subsistence, but some sport fishing also occurs. No commercial fishing occurs in the CCR.

Natives in the northern part of the CCR have traditionally been hunters but have supplemented their diet with fish (McKennan 1965). This is illustrated by an observation made in Arctic Village in August 1977. When asked about their fishing habits, a spokesman for a small group of men responded, "We eat meat." However, an hour later an old woman was seen carrying a large, freshly caught whitefish.

The dependence on fish has traditionally been greater in the southern part of the CCR where several fishing villages are found (Kunz 1977). Presently, whitefish, grayling, chum salmon and pike are the species most commonly caught by residents of the CCR (Rick Caulfield, ADF&G, Subsistence Division, and Dan Frank, Venetie resident, personal communications). In the past, suckers, sculpin and lake trout (Salvelinus namaycush) were also important food fishes (Hadleigh-West 1963; McKennan 1965), and most residents of Venetie were dependent upon the annual fall chum salmon run for food (Hadleigh-West 1963). But now chum salmon are not as important as a food source. In recent years salmon catches at Venetie have amounted to a few thousand chum salmon and only a few chinook (O. tshawytscha) salmon (Appendix Table 1). In 1981, only half the families in Venetie reported

Table 2. Scientific, common and Native names for fish species present in the Chandalar-Christian Rivers area.

Scientific Name	Common Name	Native Name 1/
Coregonus pidschian	Humpback whitefish	neeghan
Coregonus nasus	Broad whitefish	1. Khałtąįʼ El ninjIk 2. Chih Shoo 2/
Prosopium cylindraceum	Round whitefish	Khałtąįʼ
Coregonus sardinella	Least cisco	Ch'ootsik
Stenodus leucichthys	Sheefish	shryah
Thymallus arcticus	Arctic grayling	shriijaa
Salvelinus alpinus	Arctic char	łuk dahootr'įį
Salvelinus namaycush	Lake trout	neetr'aanjik
Oncorhynchus keta	Chum salmon (Dog salmon)	shii
Oncorhynchus kisutch	Coho salmon	Nehdlii
Oncorhynchus tshawytscha	Chinook salmon	łuk choo
Lota lota	Burbot	chehłuk
Esox lucius	Northern pike (Jackfish)	Eltin
Cottus cognatus	Slimy sculpin	tse hluq
Catostomus catostomus	Long nose sucker	deets'at

1/ Chandalar Kutchin language. Spellings were derived from the Kutchin alphabet as standardized by the Alaska Native Language Center, University of Alaska, Fairbanks.

2/ Peter (1979).

fishing for salmon.1/ The declining interest in salmon fishing and the absence of sculpin and suckers in the present diet of the residents of the CCR suggest that fish are not as important to these people as they once were.

Sport fishing effort is low in the CCR (Kramer 1976; Pearse 1978). In 1980 and 1981, an average of 90 angler-days were expended to harvest an average of 125 fish (primarily grayling, northern pike and lake trout) in Chandalar, Old John and Squaw Lakes and in the Chandalar River. No sport fishing was reported in either year in Ackerman Lake or in the Christian River (Mike Mills, Alaska Dept. of Fish & Game, Anchorage, private communication).

Additional information on salmon and whitefish, the species most important to the subsistence fishery, is given below.

Fall Chum Salmon

Chum salmon are not abundant in the CCR. Fall chum salmon appear to spawn mainly in the main fork of the Chandalar River below the mouth of the East Fork from mid-September to early October. Estimated escapements have ranged from 3,000 to 17,000 fish in recent years (Geiger and Andersen 1980) (Appendix Table 1). The major spawning sites are located in spring areas near or downstream from Venetie (Lance Trasky, ADF&G, personal communication). The largest spawning area known to local residents is a spring-fed slough 7 km upstream from Venetie on the west side of the Chandalar River (Dan Frank and Eddie Frank, personal communications).

The East Fork of the Chandalar River may have been a more important spawning area in the past than it is today, but the evidence for this is weak. Schrader (1900) reported that Natives caught and dried a few chum salmon at an unspecified location on the East Fork. According to Venetie residents Dan Frank and Maggie Roberts, the mouth of the North Fork of the East Fork was a major spawning area 35 years ago. People fished there in the fall for chum salmon. Roberts identified another nearby site (the mouth of the unnamed creek on the west bank of the East Fork between Big Rock and Little Rock Mountains) as an important spawning area in the 1930s. These reports appear to contradict McKennan (1965, p 17), who found no evidence of salmon utilization in the East Fork in 1933. However, the U.S. Fish & Wildlife Service reported seeing chum salmon in the East Fork as far upstream as Little Rock Mountain in 1960 (ADF&G 1982). Salmon escapements have not been surveyed on the East Fork since 1960. Consequently, little is known about its present status. Dan Frank said that he didn't

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1/ Thirteen families reported fishing for salmon (ADF&G 1981). In 1980, Venetie had 27 families (U.S. Bureau of the Census 1980).

see any salmon at the mouth of the North Fork East Fork on a trapping trip a few years ago and that his father had told him that he also hadn't seen fish there in recent years.

Because chum salmon are rarely seen in the main fork of the Chandalar River above Venetie (Louis Barton, ADF&G, private communication), aerial surveys are generally made only as far as the mouth of the East Fork. Schrader (1900), who was on a resource survey, did not report seeing any chum salmon in the main fork of the Chandalar River between the mouth of the East Fork and Chandalar Lake. In 1960, however, an unspecified number of chum salmon were observed in the main fork approximately 40 km above the mouth of the East Fork near Caro (ADF&G 1982).

Chinook Salmon

Chinook salmon are infrequently caught in the subsistence fishery at Venetie (Appendix Table 1) and are rarely seen at Arctic Village.

Schrader (1900) observed chinook salmon at an unspecified location on the East Fork, where they were caught and dried for human use, but not on the main fork of the Chandalar River above the mouth of the East Fork. Venetie resident Maggie Roberts said that she saw spawning chinook salmon at the mouth of Lush Creek near Big Rock Mountain on the East Fork in the late 1930s or early 1940s.

Whitefish

Life History. Humpback, broad and round whitefish are abundant in the CCR and are the most heavily used fish species (Rick Caulfield, ADF&G, personal communication). However, little is known about the life histories of these species in the CCR. McKennan (1965, p. 34) reported that in the 1930s the seasonal migrations of whitefish in the CCR were well known to Natives because the migrating fish could be easily caught with traps. It was known that the whitefish moved upstream to lakes in May and June and returned downstream in the fall.

Craig and Wells (1975) collected round whitefish in the Upper East Fork of the Chandalar River. They found that spawning occurred in Cane Creek beginning in late September. The females appeared to spawn annually and had a mean fecundity of 10,300 eggs. The fry appeared to move downstream to feed because they were found only below Vettetrin Lake, 20 km downstream from the mouth of Cane Creek. Fry caught on 26 July had an average length of 35.4 mm. Round whitefish in the East Fork grew more slowly than did other populations in the Chena River and the Great Lakes but grew slightly faster than did populations in Galbraith Lake on the North Slope and Summit Lake, a high-elevation lake in the Interior.

Kramer (1976) and Pearse (1978) collected whitefishes from several lakes in northern Alaska during summer. In the CCR, they found round whitefish in Ackerman Lake, where it was the most common whitefish, and in Chandalar and Squaw Lakes. Pearse's data indicated that the Ackerman Lake population grew at a relatively rapid rate (similar to the growth rate of the Chena River population reported by Craig and Wells (1975)), but that the other two populations grew at nearly the same slow rates that Craig and Wells reported for the East Fork population.

Kramer (1976) and Pearse (1978) found that the humpback whitefish was the most common whitefish in Chandalar and Squaw Lakes. Pearse's data indicated that humpback whitefish in the CCR grew more slowly than any of several other Alaskan humpback whitefish populations examined by Alt (1979). Craig and Wells (1975) examined humpback whitefish from Old John Lake and Big Fish Lake in the neighboring Sheenjek River drainage and found that their growth rates were lower than the growth rates found in several other areas, including the Colville Delta on the North Slope.

Previous records of broad whitefish in the CCR include two caught in Chandalar Lake (Kramer 1976; Pearse 1978), six caught in the outlet creek of Loon Lake (Ward and Craig 1974) and five caught in the Junjik River in the upper East Fork of the Chandalar River (Craig and Wells (1975).

Alt (1979) described various aspects of the life history of the humpback whitefish in northern Alaska, but none of his samples were collected from the CCR. In northwestern Alaska, he found that the humpback whitefish overwintered in brackish Hotham Inlet and the lower parts of the Kobuk River and then moved upstream into sloughs and lakes to feed. Those fish that would be spawning in the fall would continue moving upstream through the summer. One spawning area was about 300 km from the mouth of the river. On one occasion (30 September), spawning was observed when the water temperature was 1.5°C. Once spawned, the fish would move downstream again to spend the winter. In the Yukon River, Alt found evidence of a spawning migration in September and October near Rampart and heard a report that spawning of either humpback or broad whitefish occurred in the same area in mid-October. In the Chatanika River, humpback whitefish were found to appear in lakes and sloughs of the lower river just after ice break-up. Spawning was observed from mid-September to mid-October, about 200 km upstream from the mouth of the river. Water temperatures during this period ranged from 0 to 3°C. Although most Alaskan humpback whitefish undergo a spring migration into lakes to feed and a fall upstream migration to spawn, some populations remain in deep lakes year-round. Alt found that, in general, populations of humpback whitefish from interior Alaska grew more rapidly than populations from northern and coastal areas and attributed this to longer growing seasons in the Interior.

Alt (1976) found similar growth patterns in populations of broad whitefish in Alaska. Coastal and northern populations of the Imuruk Basin and the Sagavanirktok River were found to grow more slowly than those of the Interior and the Kuskokwim River.

Baxter (1982) found that the life histories of the humpback and broad whitefishes were similar in the Kuskokwim River. Both species overwinter in the Kuskokwim River. In March they begin to move downstream to the mouths of streams, which they enter later for summer feeding. In May the fish move up these streams and into tundra lakes before the break-up of winter ice. All growth appears to occur during the summer feeding period from May to August. Some of the lakes are cut off from the streams in summer when water levels are often lower than they are in the spring. Whitefish feeding in these lakes would depend on fall rains to raise the water level and allow them to return to the Kuskokwim River. The shallow tundra lakes become anoxic in winter, and so a failure of the appearance of fall rains could result in the death of trapped whitefish. Catches of gravid and non-gravid fishes suggest that the whitefish spawn every other year. This may be due to a growing season that is too short for the fish to recover from the stresses of spawning. Fish ready to spawn start leaving the lakes in August and non-spawners leave between September and December. Spawners, caught in the Kuskokwim River during their upriver migration in the fall, are noticeably "fatter" than non-spawners. Spawning begins in the Kuskokwim River in late October, when the water temperature falls to $0^{\circ}C$, and continues through early December. Neither the spawners nor the non-spawners feed during the fall and winter.

Baxter (1982) found a few behavioral differences between the humpback and broad whitefishes. He found that the humpback whitefish moved farther upstream and inhabited clearer and swifter portions of the stream than did the broad whitefish, although the humpback whitefish was also found wherever the broad whitefish was found. The feeding habits of the two fish were found to be similar, except in one lake where the humpback whitefish fed on nekton and the broad whitefish fed on benthic organisms. Baxter also observed that juvenile broad whitefish moved out of the summer feeding areas in a relatively concentrated migration compared to the migration of juvenile humpback whitefish, which was dispersed over several months.

Vining (1982) studied the food habits of humpback whitefish in a small lake in the upper Tanana River. He found that the fish entered the lake in the spring to feed and left in the fall to spawn. The fish's food consisted primarily of chironomids and cladocerans. The chironomids appeared to be more important when visibility was good, i.e., in shallow water and during daytime. The cladocerans were more important during dusk and in deep water.

<u>A Possible Decline in Whitefish Habitat in the CCR</u>. Shallow lakes are abundant in the Yukon Flats and upper East Fork

Chandalar River basin and are thought to be important summer feeding areas for whitefish. Residents of both Arctic Village and Venetie told us that water levels in these lakes have been declining over the past 30 years and that whitefish harvests have also declined simultaneously. We examined weather records and aerial photographs to see if they were consistent with these reports.

In permafrost regions, permafrost helps to prevent lakes from losing their water by lowering the permeability of the ground. The temperature of the permafrost layer may be increased by increases in mean annual temperature or mean annual precipitation (Williams 1970). If the temperature of the permafrost is close to its melting point, a small increase in temperature may result in a reduction of permafrost. Ironically, an increase in precipitation may result in lower water levels in lakes in permafrost regions.

Permafrost in the CCR is discontinuous and, thus, has an expected range in temperature between 0 and -5°C (Williams 1970). Permafrost temperatures are not available for the CCR, but in the Fairbanks area Williams found temperatures around -0.7°C. Thus, permafrost in the CCR may be vulnerable to small increases in mean annual temperature and precipitation.

U.S. Weather Bureau (1918-1980) records indicate that between 1918 and 1980 the mean annual temperature in Fort Yukon increased by 0.96°C ($r=0.22$, $P<0.1$) (Fig. 3), and, between 1918 and 1973, annual precipitation increased by 3.8 cm ($r=0.25$, $P<0.1$) (Fig. 4). The increase in temperature at Fort Yukon is in agreement with a report by Hamilton (1965), who found increasing temperature trends in several areas of Alaska. In Fairbanks, Hamilton found a net increase of 0.6°C in the mean annual temperature between 1910 and 1962. During the period 1918 to 1962, the mean annual temperature in Fort Yukon increased by 0.7°C.

Possible evidence of a warming trend in the CCR is given by McKennan (1965, p. 18). Older Natives told him that spruce, birch and tall willow trees had become common in the CCR in the 1930s, where at an earlier time they had been scarce. However, these observations might also be explained as the recovery from a forest fire.

Stereoscopic aerial photographs of the Venetie area (NASA 1980) show two distinct water level benchmarks in lakes. The benchmarks indicate a drop in water level, possibly in two major stages. By comparing the height of the drop with the height of willows growing along the lake shores, the overall drop in lake levels appeared to be about 1 m. The resolution of aerial photographs of the same area taken earlier (U.S.G.S. 1955) was not high enough to identify the benchmarks.

These weather and photographic records are consistent with reports that lake levels in the Venetie area have been declining during the past 30 years, but they do not confirm them.

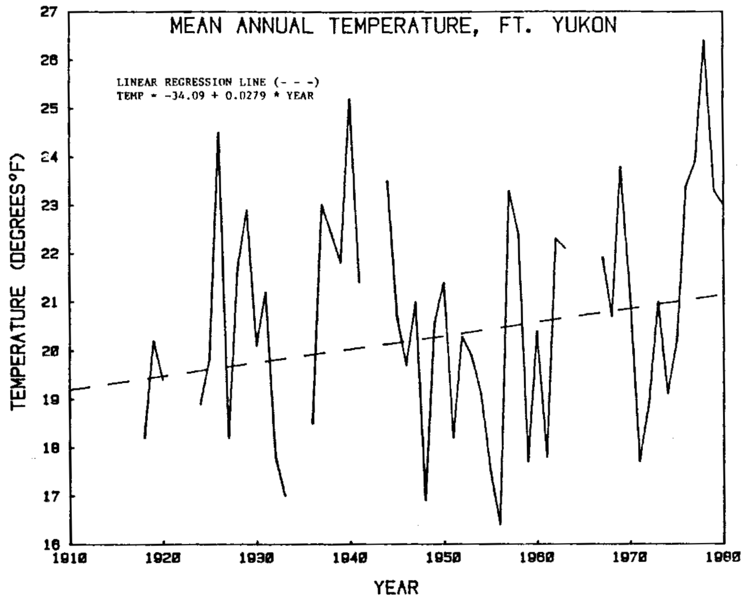

Figure. 3. Mean annual temperature at Fork Yukon, Alaska, 1918 to 1980.

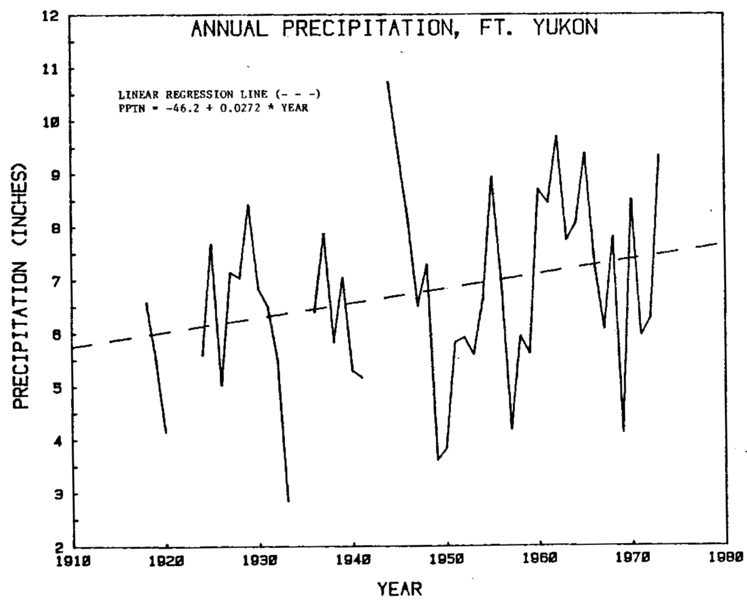

Figure 4. Annual precipitation at Fort Yukon, Alaska, 1918 to 1973.

Field Studies

Chum Salmon

On 23 March 1982, we visited a slough on the Chandalar River (7 km upstream from Venetie) in which chum salmon were known to spawn. A small, ice-free area near the bank of the slough identified a submerged spring. Elsewhere in the slough, ice thickness ranged from 60 cm to 90 cm. Water depths in the slough ranged from about 2 to 5 m (Fig. 5). Twelve chum alevins, having an average length of 37 mm and an average weight of 250 mg, were recovered from the gravel in the spring. The alevins had consumed their yolk sacs and appeared to be within two weeks of emergence. Intragravel water temperatures in the spring were 1.2 to 2.3°C, while water temperature elsewhere in the slough was 0°C.

Whitefish

We attempted to collect whitefish in four lakes and in the above-mentioned slough. We were unable to return to two of the lakes--Loon Lake and Venetie Lake--in the spring because the Venetie Tribal Government did not respond to our request to reenter the reservation.

Loon Lake. Located near Arctic Village, Loon Lake is approximately 1.6 km long and is drained by a creek that flows through the village into the East Fork Chandalar River (Fig. 6). Loon Lake appears to be the lowest lake in a lake system that has a total surface area of 6.4 km^2.

Ward and Craig (1974) reported that Loon Lake is "moderately deep" and supports a permanent northern pike population. Craig and Wells (1975) examined six whitefish caught in the outlet creek to Loon Lake on 26 June 1972. All were broad whitefish with lengths from 42.0 to 49.5 cm, weights from 934 to 1,561 g and ages from 7 to 13 years (Appendix Table 2).

On 3 February 1982, we examined six fish that were caught in Loon Lake by Peter Tritt, a local fisherman. Tritt caught the fish with a gill net that was set under the ice. All of the fish were broad whitefish. The lengths ranged from 39 to 48 cm, and the ages ranged from 8 to 13 years (Appendix Table 2). The stomach of one fish was full of small snails (*Lymnea atkaensis* and *Valvata sincera*), clams (*Sphaerium nitidium*), and unidentified organic material. Water temperature was 0.8°C and dissolved oxygen concentration was 8 ppm.

The migration pattern of broad whitefish in the East Fork is not known, but a model can be constructed based on Peter Tritt's observations at Arctic Village and what is known of broad whitefish elsewhere in Alaska. Tritt said that the broad whitefish that overwinter in Loon Lake leave the lake after ice break-up in the East Fork (probably in late May). These fish have full egg sacs, are "fat", and have stomachs full of small snails and clams. At the same time, other broad whitefish migrate up the East Fork. These fish have empty stomachs and are lean. Tritt also said that whitefish with empty egg sacs return to Loon Lake in August.

Similar observations were made by Bryan (1973) in the Porcupine River near Old Crow. Bryan observed that broad whitefish that had overwintered in Fish Lake had large amounts of visceral fat during their migration out of the lake in early June. On the other hand, broad whitefish captured at the same time in the Porcupine River and which had apparently overwintered in the Porcupine River were lean.

A possible explanation of these observations is that the East Fork and Porcupine River broad whitefish are non-consecutive spawners and alternate their overwintering areas: winters preceding a spawning year are spent in a lake, and winters following spawning are spent in a river (Ken Alt and Rae Baxter, private communications). A possible reason for this is that access to the overwintering lakes may be cut off by late September when spawning is probably completed. The spawners would thus be forced to overwinter in the main river. Non-spawners appear to enter the lakes in August before the water levels fall. This model is rather speculative since it is based on only a few observations.

Shovun Lake. Located 27 km north of Fort Yukon, Shovun Lake is part of an extensive network of creeks and lakes that empty into the Christian River (Fig. 7). To our knowledge, the fish resources of this system have not been previously investigated. Alexander's Village on the lake's outlet used to be an important fishing camp.

We visited Shovun Lake 14-17 June 1982. The main body of the lake was about 10-11 m deep, while arms and near-shore areas were typically 2-3 m deep. Submerged vegetation indicated that the water level was about 1 m above normal at the time of our visit. Surface water temperatures ranged from 16.0 to 20.0 $^{\circ}$C on 14 June and 15 to 16 $^{\circ}$C on 16 June.

Roughly 140 m^2 of gill net were fished for 60 hours. One broad whitefish, a 4-year-old, 279-mm-long male, was caught in a shallow bay on the west side of the lake. Another broad whitefish, an 8-year-old, 425-mm-long female, was caught in deep water at the center of the lake. The stomach contents of the two fish consisted of small clams and snails, organic muck and small (2- to 4-cm) reddish-colored leeches.

Twentymile Lake. Located 30 km northwest of Fort Yukon (Fig. 8), Twentymile Lake is also part of the lake system that empties into the Christian River. Twentymile Lake used to be an important summer whitefish subsistence fishing area (Silas John, resident of Venetie, and Rick Caulfield, ADF&G, personal communications).

Local residents thought that whitefish overwintered in the lake (Dan Frank, personal communication).

On 25 March 1982, we set 26 m of gill net (25- to 100-mm stretch mesh) 50 cm under the ice at a location that Dan Frank said was the deepest area in the lake. Water depth, measured from the ice upper surface, was 5.3 m. Snow depth was 20 cm. Ice thickness was 1.2 m. Air temperature was -16°C. One amphipod was washed up through the ice by the ice auger.

The net was retrieved the next morning, 14 h later. No fish were captured. Water temperature was 0°C and the dissolved oxygen concentration was 2.0 ppm. Surface water visibility was less than 1.2 m. Two vertical, 4.7-m plankton hauls were made with a 15-cm-diameter, 243-um mesh net. Part of the sample leaked from its container, so an accurate plankton density couldn't be calculated. From a visual estimate of at least 1,000 zooplankters in the original sample, we estimated that the zooplankton density was at least 6,200 organisms/m^3. The sample was composed entirely of the copepod *Cyclops* sp.

Shallow lakes become hypoxic in winter, while deeper lakes, generally those deeper than 5 m, may retain enough oxygen to support a winter whitefish population (Ken Alt, personal communication). The 5.3-m depth that we observed in what we thought was the deepest point in Twentymile Lake was close to the critical depth. The low dissolved oxygen concentration that we observed was probably a result of the shallow depth and was probably too low for whitefish (Ken Alt, personal communication).

Chandalar River. We found a calm, relatively deep pool in the Chandalar River near Venetie (Fig. 5) that looked like a likely place to find overwintering whitefish. On 23 March 1982, we set 15 m of 100- to 125-mm square mesh gill net under the ice at this location for 26 h. No fish were captured.

Venetie Lake. Located 5 km east of Venetie in the Chandalar River drainage, Venetie Lake is about 3 km in diameter (Fig. 9). In past years, Venetie Lake and its outlet creek had a large summer population of whitefish which supported a local fishery between late May and early September (Hadleigh-West 1963; Silas John, Dan Frank and Rick Caulfield, personal communications). The native name for the fish 1/ and a sketch by Dan Frank of the fish's nuchal hump, brow and snout indicate that it was a broad whitefish. The main channel of Kocacho Creek used to flow through an arm of Venetie Lake (Fig. 11). Thus, the upstream portion of Kocacho Creek was one of the lake's inlets, and the

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1/ Dan Frank called the fish a "Che Sol" (our spelling). The Kutchin name for broad whitefish is Chih Shoo in the Chandalar area (Peter 1979) and Chii sth in the Old Crow area (Steigenberger and Elson, 1977).

downstream portion was the lake's outlet. Whitefish probably entered and left the lake through the outlet channel. Most of the fish were caught in the narrow passage that joins the arm to the main body of the lake. A drainage area about 3 km wide and 13 km long on the northwest side of Venetie Lake is clearly visible on aerial photographs. Dan Frank said that this area was once swampy and an important water source for Venetie Lake.

In the late 1930s the inlet and outlet were blocked by natural causes, and the creek eventually shifted its flow to another slough to the east (Silas John and Dan Frank, private communications). U.S.G.S. aerial photos confirm that the shift occurred before 1955. Venetie Lake may have been further isolated from Kocacho Creek by a drying of the once swampy watershed on the northwest side of the lake. Dan Frank said that this area was now drier than it had been.

On 22 March 1982, we drilled 13 test holes in the lake ice (Fig. 10, Appendix Table 3). Air temperature was 6°C. Snow depth was 30 cm and ice thickness was 110 cm. Water depths (ice surface to bottom) ranged from 1.8 to 3.0 m. Water temperature was 0.1°C. Dissolved oxygen levels ranged from 0.5 to 2.0 ppm. A moderate-to-strong hydrogen sulfide odor was noted at each hole. Amphipods, about 1.5 cm long, were brought up by the ice auger at six of the test holes in densities from about 1 to 20 per liter of water.

On the same day we also inspected part of the old Kocacho Creek channel labeled "inlet" in Figure 11. This channel was roughly 10 m wide and had steep, 2- to 3-m high banks. The upper end of the channel bottom appeared to be about 1.5 m higher than the ice surface on Kocacho Creek. Two earth-filled dams, approximately 1 m high, blocked different parts of the inlet channel. An additional earth-filled dam was located from the air on 26 March 1982 on the old outlet channel of Venetie Lake (Fig. 11). These dams appeared to be fills to allow heavy equipment to cross the channels.1/

We drilled a hole through the ice on Kocacho Creek on 22 March to see if water was flowing under the ice. The ice thickness was 1.9 m. The water layer under the ice was was 50 cm thick, but, because of the thickness of the ice, we were unable to estimate the flow. The ice on Kocacho Creek was thicker than that on Venetie Lake because of overflow ice formation on the creek.

Aerial photographs of the old inlet and outlet channels of Venetie Lake were taken on 23 May 1982 when water levels were thought to be at their highest of the year. Kocacho Creek was

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1/ Local residents said that a heavy equipment trail was constructed 4 to 6 years ago. However, in the middle of one of the inlet dams we found an 11-year-old alder.

approximately 12 m wide and appeared to be flowing swiftly and at the top of its banks. The flow was estimated at 23 m^3/s using estimates of depth and velocity of 3 m and 61 cm/s (2 ft/s). Water was more visible on the upstream side of the two inlet channel dams than on the downstream side which made it appear that the dams were blocking the flow of Kocacho Creek water into the inlet channel. The swampy area to the northwest of the lake was very wet and appeared to be the major source of water for the lake. Discharge from the lake was backed up on the upstream side of the outlet channel dam. Thus, even during periods of high water, the lake appeared to be cut off from the stream system.

In summary, our observations indicate that three factors have contributed to the loss of water in the outlet channel, the route by which whitefish would probably enter and leave Venetie Lake:

1. Kocacho Creek has shifted from the old channel to the present channel that bypasses the lake.

2. The inlet dams (Fig. 11) make it more difficult for Kocacho Creek water to flow through the old channel during periods of high water.

3. Presently, Venetie Lake's main water source is the swampy watershed on the lake's northwest side. The discharge of this water through the old channel is hindered by the outlet dam (Fig. 11).

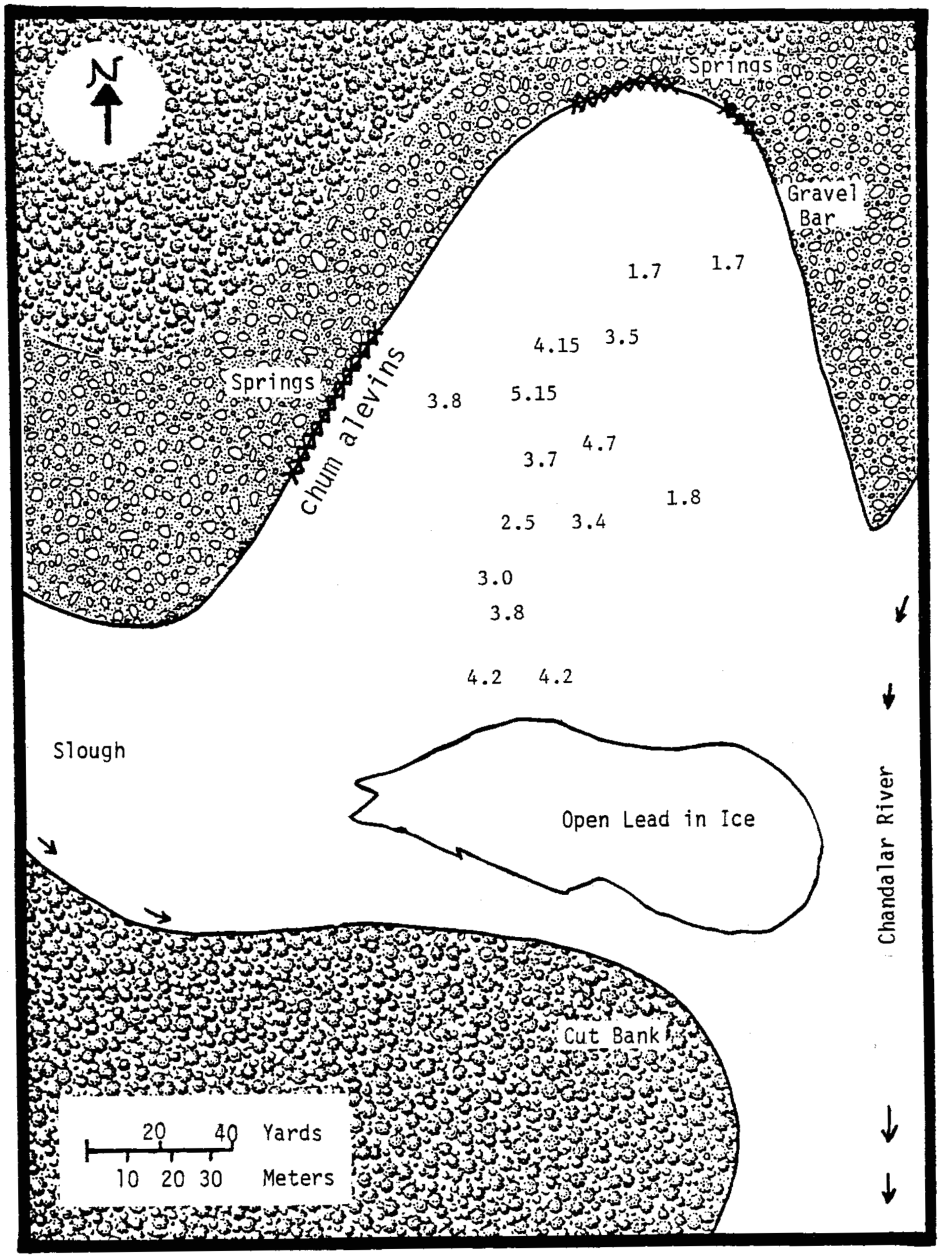

Figure 5. Map of a Chandalar River spring and backwater 7 km upstream from Venetie. Water depths, measured from the top surface of the ice on 23 March 1982, are shown in meters.

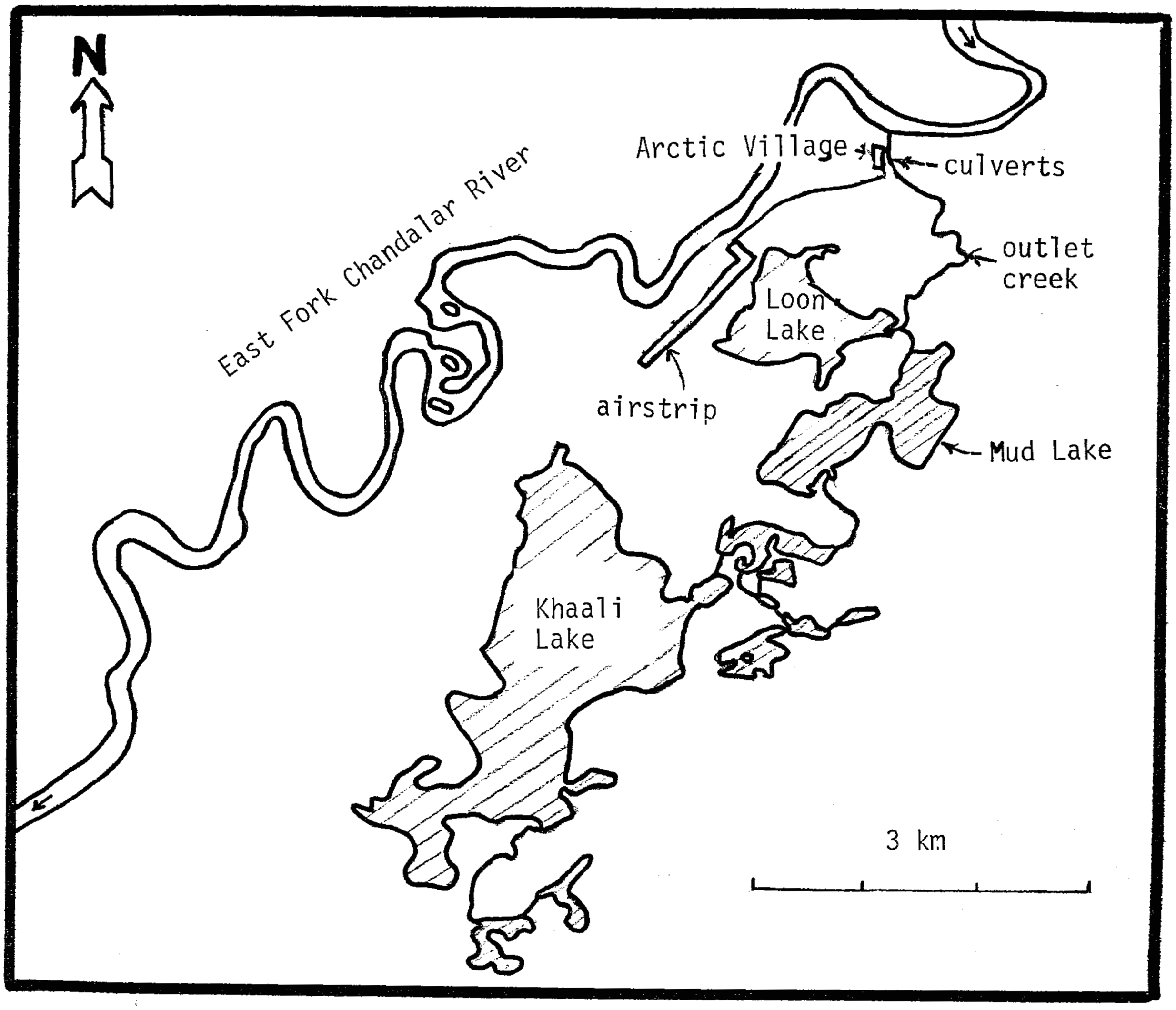

Figure 6. Map of the Loon Lake system near Arctic Village.

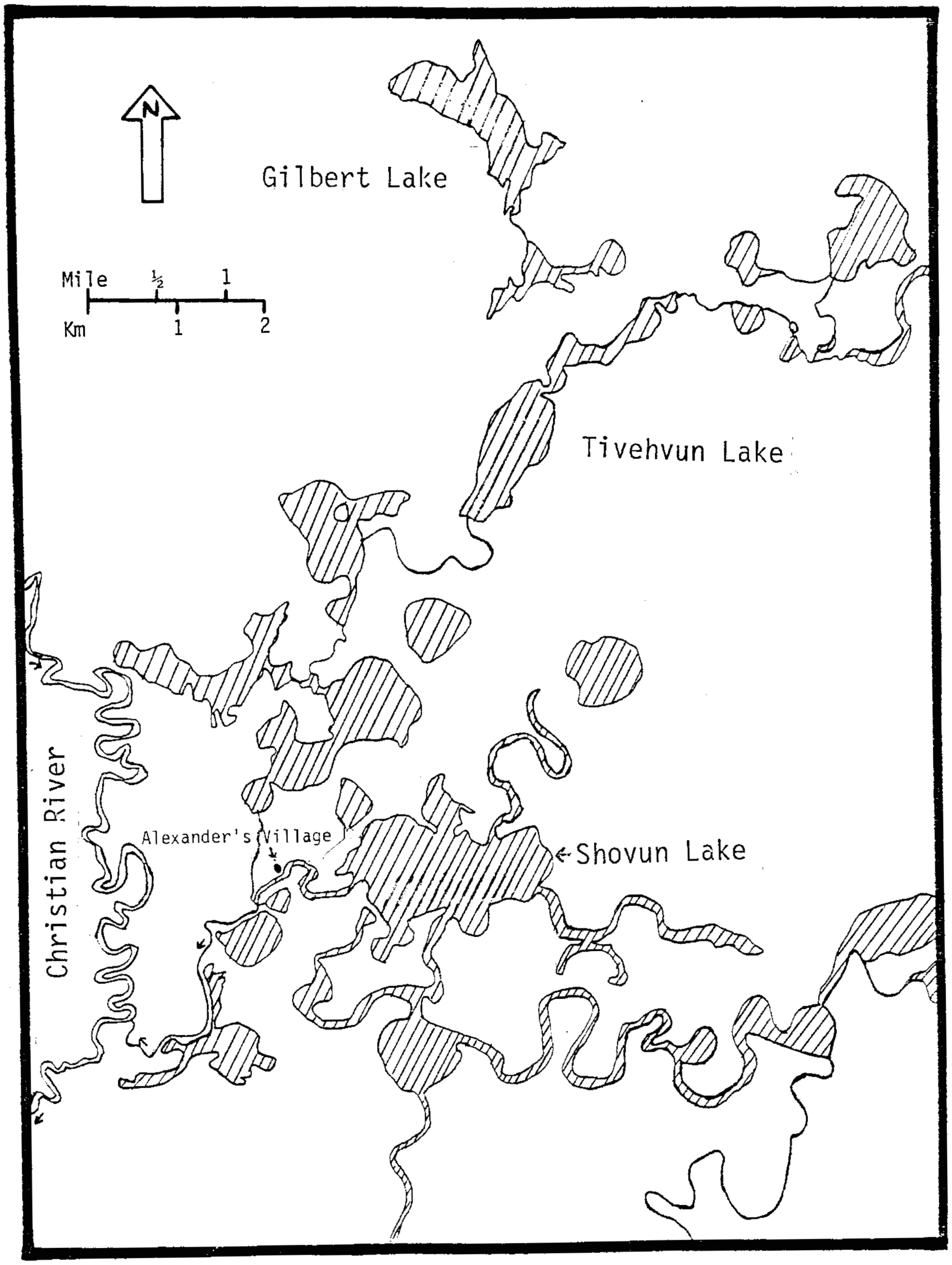

Figure 7. Map of Shovun Lake and interconnecting lakes 27 km north of Fort Yukon.

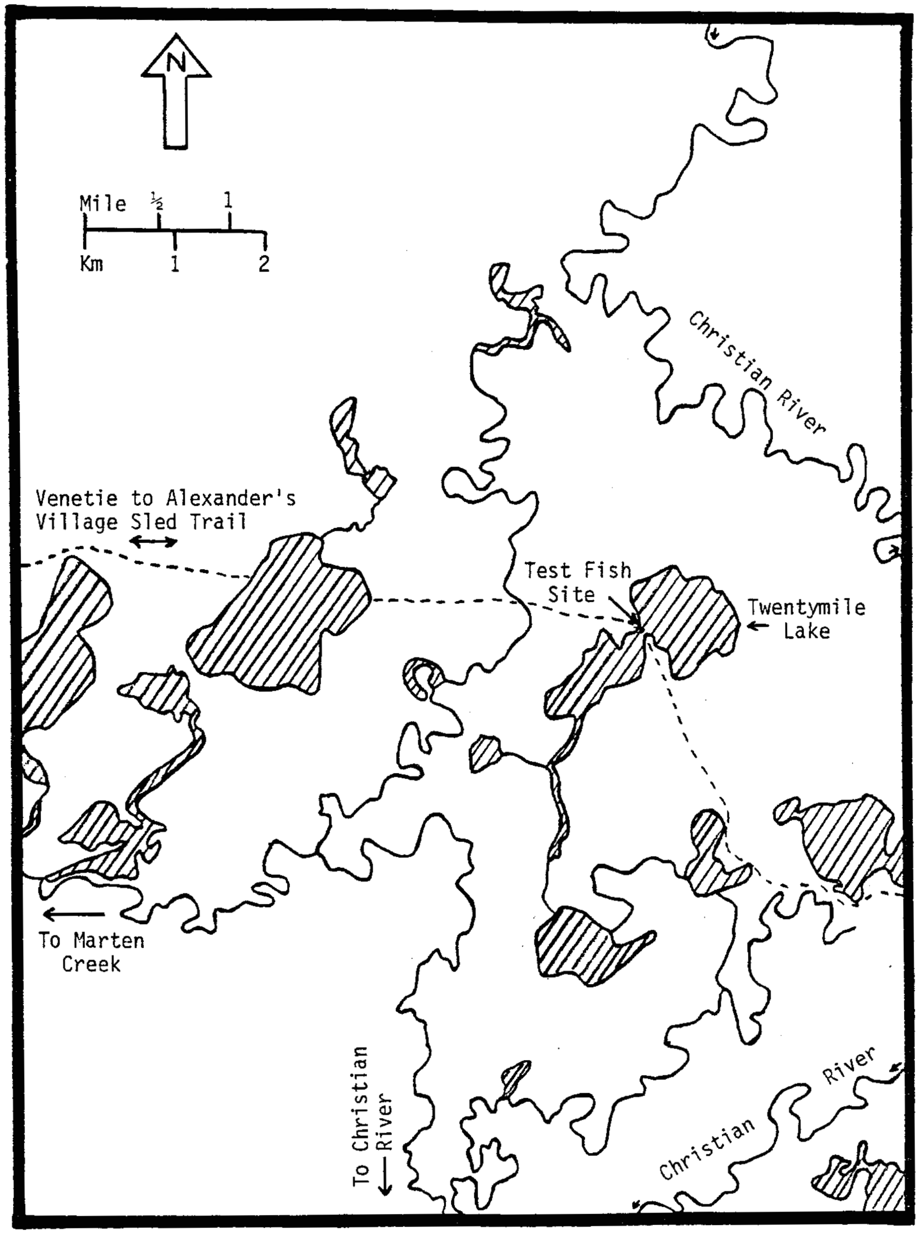

Figure 8. Map of Twentymile Lake and neighboring lakes 30 km northwest of Fort Yukon.

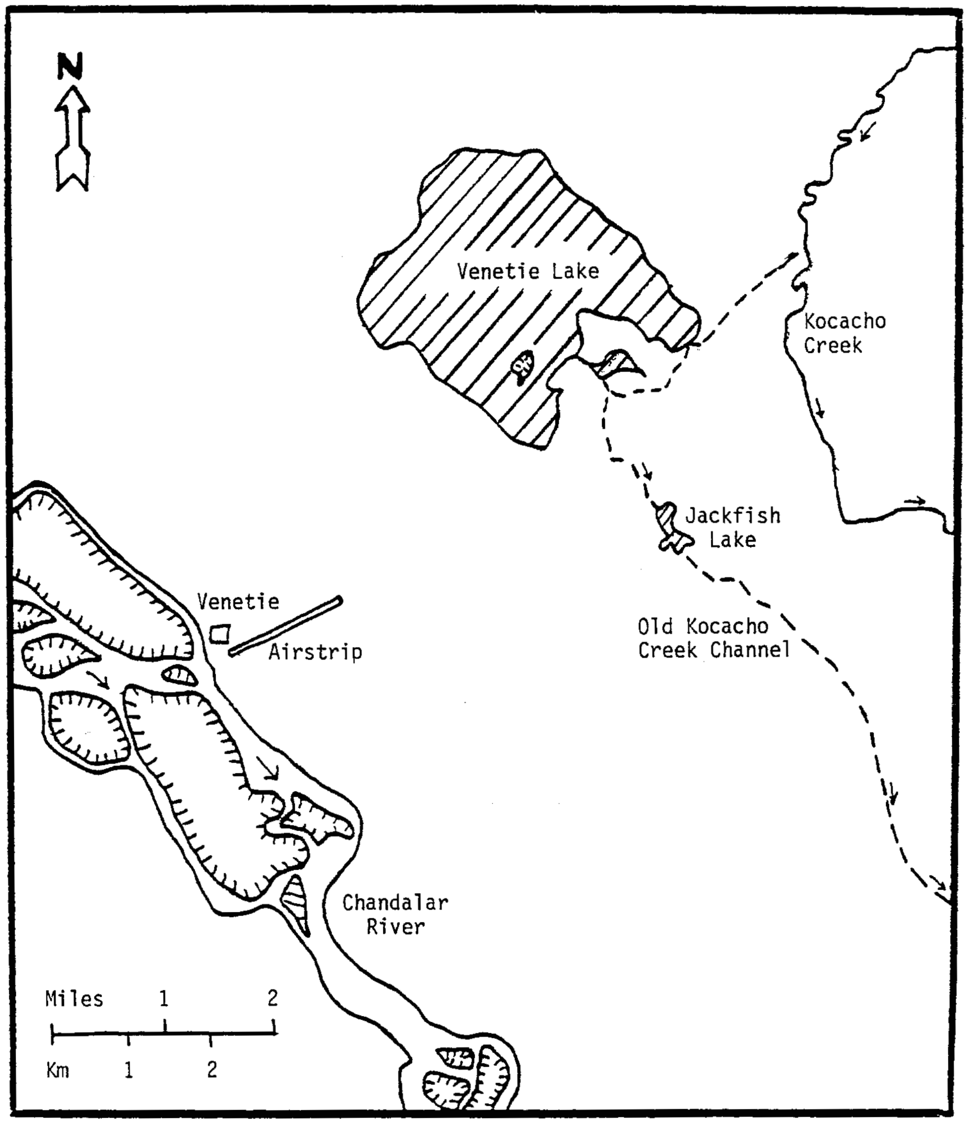

Figure 9. Map of Venetie Lake and Kocacho Creek near Venetie.

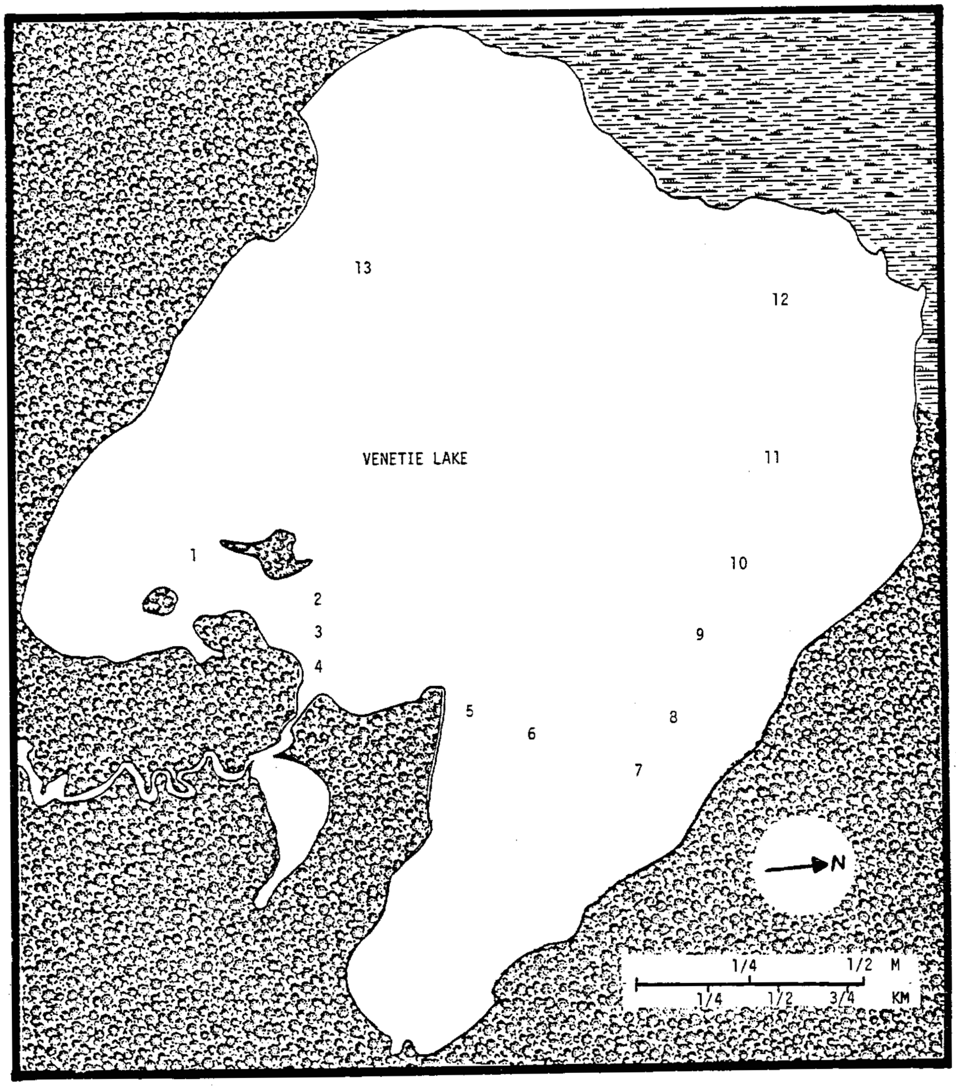

Figure 1Ø. Map of Venetie Lake showing locations of test holes drilled on 22 March 1982.

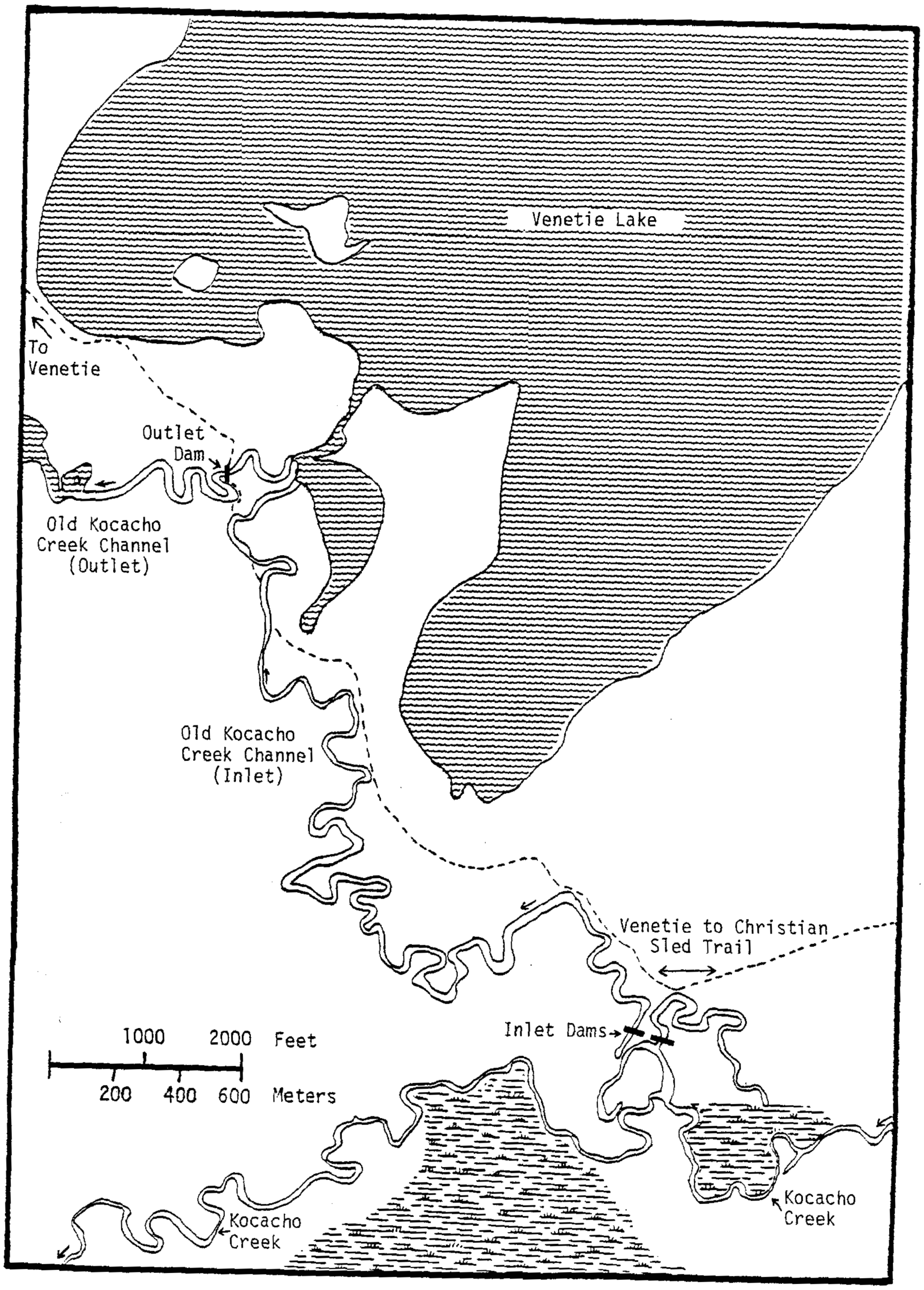

Figure 11. Map of the former inlet and outlet channels of Venetie Lake.

Factors Limiting Fish Production in the CCR

Salmon

The reasons for the absence of chinook salmon in the Chandalar River and the absence of chum salmon in the North, Middle and East Forks are not clear. Three possible factors are low water temperature, low food abundance and poor water quality.

Water temperatures in the Chandalar River near Venetie normally remain at 0°C from early October to early May (U.S.G.S. 1968-1974) (Appendix Table 6). In contrast, temperatures in the Chena River (200 km south of the CCR) remain at 0°C from about late November to early March (Frey et al. 1970, Table 7), a much shorter period. The lower temperatures in the Chandalar River make it more difficult for chum and chinook eggs and alevins to develop in time for a spring emergence.

Low food abundance is another possible factor limiting chum salmon, but few data are available to confirm this. Craig and Wells (1975) measured densities of benthic invertebrates in the East Fork of the Chandalar River about 50 km upstream from Arctic Village in late July. They found a relatively low density of 18 organisms/m^2 in the main river and higher densities of 321 and 1,562 organisms/m^2 in nearby tributaries. In contrast, benthic invertebrate densities in the Chena River near Fairbanks averaged over 3,000 organisms/m^2 in July and August (Frey et al. 1970).

Water quality may also be a problem in the upper parts of the Chandalar River drainage. High concentrations of metals have been found in stream sediments in the upper North and Middle Forks (Brosge' and Reiser 1972). Concentrations ranged as high as 0.2 ppm gold, 160 ppm silver, 400 ppm zinc, 15 ppm antimony, 15 ppm molybdenum, 90 ppm copper and 1,000 ppm lead (where ppm refers to parts per million parts of sediment). Concentrations of these metals in the water were not reported and cannot be accurately inferred from the concentrations in the sediments.

Recommended maximum concentrations of iron and manganese for aquaculture are 100 and 10 ppb, respectively (ADF&G 1977). Water samples taken from the upper East Fork of the Chandalar River at Arctic Village in May 1979 and June 1980 had iron and manganese concentrations 20 times these levels (Appendix Tables 7 and 8). In contrast, concentrations in winter at the same location were generally lower. A January water sample (Appendix Table 9) had undetectable amounts of iron and manganese, and a March water sample (U.S. Geological Survey 1971) contained 150 ppb iron and 40 ppb manganese. The lower levels in winter suggest that the high springtime concentrations arose from drainage of mineralized soils.

Grayling, sculpin and other fishes live in these waters but may have greater tolerances for metal pollutants than salmon. In one mineralized area in northwestern Alaska, sculpin, arctic char (Salvelinus alpinus) and grayling were found to inhabit waters closer to the source of contamination than chum and pink O. gorbuscha) salmon (Dames and Moore, Inc. 1981).

Water quality in the main fork of the Chandalar River (where chum salmon are found) appears more suitable for fish. Each of several water samples that were taken in July 1977 from the Chandalar River near Venetie (Appendix Table 10) met aquaculture water quality standards (ADF&G 1977). The density of benthic invertebrates has not been measured in the main fork.

Whitefish

Broad and humpback whitefish in the CCR appear to be among the slowest growing populations of these species in the state. The age-length relationship of 14 broad whitefish taken from two lakes in the CCR (Appendix Table 2) is similar to that reported for populations in the Imuruk Basin and Sagavanirktok River (Alt 1976). Each of these populations was relatively slow-growing, compared to populations examined by Alt from the Holitna River, Minto Flats and the Porcupine River. The growth rates of humpback whitefish from Chandalar, Old John and Squaw Lakes (Pearse 1978) are also low, compared to the growth rates of populations from several other parts of the state (Alt 1979). Alt speculated that the slow growth rates of broad and humpback whitefish in the North Slope and in northwestern Alaska might be due to shorter growing seasons in these areas. Low food availability and genetic factors were suggested as secondary causes. It is odd that broad and humpback whitefish grow more slowly in lakes in the CCR than they do in the nearby Porcupine River. Alt (private communication) speculated that this difference in growth rates might also be due to a shorter growing season since the lakes might warm more slowly in the spring than the rivers.

The whitefish population in the CCR may have declined in the past 30 years as local residents claim. We were unable to find any direct evidence to support this, but we did find indications that lake levels have dropped. Lakes are important summer feeding areas for whitefish and may become inaccessible from the stream system when water levels are low. Near the villages, man-made factors may also be important. Damming of the the inlet and outlet channels to Venetie Lake has contributed to the low water level in the lake and has made it unlikely that fish could reach the lake from Kocacho Creek during the high-water period in the spring. At Arctic Village, culverts on the inlet channel to Loon Lake and potential run-off of polluted water from the new airport into Loon Lake may have made this lake less attractive to whitefish. Also, the populations in these villages have more than tripled between 1939 and 1970 (U.S. Department of Commerce 1950, 1970) and may have contributed to overfishing. We conclude that a decline in the whitefish population in the CCR is possible, but difficult to confirm.

Rehabilitation and Enhancement Opportunities

Salmon

An attempt to identify water sources for a salmon hatchery primarily consisted of a search of the literature on waters in the CCR. Bodies of water previously investigated and the type of data available on them are given in Appendix Table 4. A summary of additional information on 13 springs in the CCR is given in Appendix Table 5.

It appears that none of these sites or springs is suitable for a conventional flow-through salmon hatchery because of low water temperature, low water flow or poor access. Other types of salmon enhancement, such as instream incubation, planting of eyed eggs and rehabilitation of spawning habitat (McLean and Raymond, 1981, p 30), are probably infeasible because of the remoteness of most of the CCR.

Fall chum and chinook salmon could probably be successfully produced at either Venetie or Arctic Village (by using recirculated water for incubating chum eggs and by releasing chinook fingerlings in the fall 1/), but salmon enhancement in the CCR presently appears unwise for five reasons. (1) Both of the above methods are experimental and need further testing before they could be used on a large scale. (2) Most of the salmon produced

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1/ Fall chum salmon spawn in springs where water temperatures are slightly higher than they are in the main river in winter. Fall chum salmon eggs could be incubated in a small hatchery in which most of the water is recirculated to reduce heating costs. Although additional testing is needed, it is expected that such a hatchery could incubate one million eggs with a flow of only 10 liters of water per minute (Raymond 1981; Raymond, unpublished data).

Chinook eggs do not appear to require elevated water temperatures throughout the winter since they remain in the gravel for a longer period than chum eggs. Chinook eggs could thus probably be incubated with river water at ambient temperature. Chinook salmon also differ from chum salmon in that they require a year of rearing in fresh water before they migrate to sea. It is probably uneconomical to keep chinook salmon fry for a full year in a remote facility, but a large part of the rearing and holding costs could be avoided by releasing the chinook salmon as fingerlings in the fall before freeze-up. A fall release would not put as great a strain on the local food supply as would a summer release because chinook fingerlings would not feed actively during the winter months.

in the CCR would be caught in the Yukon River fisheries rather than in the CCR. (3) The quality of the returning salmon after their long upstream migration would probably be marginal. This is reflected in the reduced fishing effort for chum salmon in the CCR as other foods have become available in recent years. (4) Water quality in the East Fork of the Chandalar River may not be suitable for salmon. (5) Perhaps most importantly, the carrying capacity of the Chandalar River for juvenile fish is unknown and could easily be exceeded by a large release of salmon. This could also harm the wild chum salmon stocks.

Whitefish

If reports that the whitefish population in the CCR has declined in the last 30 years are true, how might the whitefish be rehabilitated? Humpback whitefish have been produced in hatcheries in Canada since the early 1900s, but there is little evidence that the hatchery-produced fish have resulted in increased catches (Miller 1946; Dymond 1956; Lapworth 1956). Miller believed that food availability was the limiting factor. The cause of the low growth rates of broad and humpback whitefish in the CCR is not known, but low food availability is a possibility. In view of the existing lack of knowledge on food availability in the CCR, further study of this subject should precede any plans for hatchery development. For the present, habitat improvement at Venetie Lake and Loon Lake appears to be the safest and most worthwhile course of action for whitefish rehabilitation in the CCR.

Venetie Lake. The loss of a summer whitefish population in Venetie Lake appears to be the result of isolation of the lake from Kocacho Creek by natural or man-made causes. Possible natural causes include a lowering of water levels and a migration of Kocacho Creek away from Venetie Lake. Possible man-made causes are the three earthen dams that block the lake's inlet and outlet channels.

Although we are not sure which of these factors is most important, the small cost for removing the dams should make this project well worth undertaking. Whitefish move upstream into lakes for summer feeding. Thus, removal of the earthen dam that is currently blocking the outlet channel (Fig. 11) may be all that is needed. In the spring the influx of water from the swampy drainage area on the northwest side of Venetie Lake may provide enough discharge from the lake to allow whitefish to enter from Kocacho Creek. However, since we are not certain that the outflow would be sufficient, the earthen dams that are blocking parts of the inlet channel should also be removed since they may be preventing water from entering the lake during periods of high water in Kocacho Creek.

If removal of the dams fails to reconnect Venetie Lake to Kocacho Creek, extension of the inlet channel to a point farther upstream on Kocacho Creek should provide enough water to the lake to keep the outlet channel open.

The hypoxic water that we observed in Venetie Lake in March should not be a deterrent to whitefish since many lakes inhabited by whitefish in the summer become hypoxic in winter after the fish leave the lakes. The loss of ice cover and influx of water in the spring should raise the oxygen levels to acceptable levels for whitefish.

Loon Lake. In recent years, two adjacent culverts were placed in the outlet creek of the Loon Lake system to accommodate a new road, and the Arctic Village airport was extended near the lake. Local residents have said that the whitefish catch in this creek has dropped since these projects were completed and wondered whether the projects were responsible (Trimble Gilbert and Bill Bjork, personal communications). We observed both the culverts and the airport extension on 3 February 1982. The culverts were approximately 15 m long and 1 m in diameter. The bottoms of both ends of the culverts were approximately 30 to 40 cm above the ice surface in the creek. Thus, an earthfill supporting the culverts appeared to be blocking the flow in the creek during periods of low water. The airport extension, which included an airplane parking and fueling apron, was made on the airport's north end. This area is located about 250 m from Loon Lake on a slight rise which slopes into the lake. Local residents did not know of any past oil spills.

In order to determine if the Loon Lake whitefish population has declined, several factors need to be investigated. In the outlet creek, these include hydrocarbon levels, fishing pressure, water velocities and flows in the culvert during the migration periods. In the lake, these factors include temperatures, dissolved oxygen levels, depths (which determine winter dissolved oxygen levels), abundance of food and competition from other fishes. We also need to determine if the entire Loon Lake system is accessible to fish movement. It is possible that some of the interconnecting channels may have become impassable to fish movement, thus reducing the amount of available fish habitat.

Local Opinions Concerning Rehabilitation and Enhancement

Residents of Venetie and Arctic Village appeared to strongly favor maintaining a subsistence fishery for salmon and whitefish in the Chandalar River. None of the local residents whom we contacted wanted to develop a commercial salmon or whitefish fishery.

One resident of Arctic Village (Sam Sam, personal communication) and several residents of Venetie (Dan Frank, Eddie Frank, and Silas John, personal communications) were concerned that a gradual drying of local lakes would reduce the whitefish population.

In Venetie, several older people expressed a desire to rehabilitate Venetie Lake to provide a local source of whitefish. The village council previously had considered using a bulldozer to reopen the lake outlet channel but has not acted because of permit restrictions and uncertainity of what to do.

Residents of Arctic Village who want to fish for chinook salmon for subsistence now go to Fort Yukon or Venetie Landing since chinook salmon are not found in the East Fork of the Chandalar River. Several residents said that they would like the State to develop a local chinook salmon subsistence fishery by releasing chinook salmon fry near Arctic Village. The village council had previously discussed this idea.

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We thank the many residents of Venetie, Arctic Village and Fort Yukon who contributed to this study for their assistance and hospitality. Special thanks are extended to Dan Frank of Venetie for his hospitality and expert guide service. We also thank Ken Alt and Rae Baxter for valuable comments on whitefishes and Ken Leon and Mark Kissel for critically reading the manuscript.

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Appendix Table 1. Chandalar River fall chum and chinook salmon subsistence catches and escapements, 1961-1981. 1/ Subsistence catches are for Venetie Village. No chinook salmon were observed during escapement surveys.

Year	Chinook Catch	Chum Catch	Chum Escapement
1960	50	6,000 2/	
1961	-	-	
1962	-	1,000	
1963	-	200	
1964	-	-	
1965	-	9,856	
1966	-	1,098	
1967	-	2,626	
1968	-	551	
1969	7	3,116	
1970	10	2,400	
1971	-	801	
1972	-	50	
1973	-	410	
1974	-	-	17,455
1975	-	2,401	6,345 4/
1976	-	508	58 4/
1977	-	1,660	4,183
1978	9	2,606	-
1979	0	3,943	-
1980	160	2,730	2,986
1981	-	1,450 3/	4,906 5/
1982	-	-	1,126 5/

1/ Geiger and Andersen, 1980.
2/ ADF&G, 1982.
3/ Preliminary estimate.
4/ Poor or incomplete survey; minimal estimate.
5/ Fair-poor survey; more fish present.

Appendix Table 2. Age and length of broad whitefish, _Coregonus nasus_, caught in the Chandalar-Christian Rivers area.

Location	Age	Length(mm)
Loon Lake	8	388
	8	419
	9	432
	12	455
	13	432
	13	476
Loon Lake 1/	7	447
	8	431
	9	454
	10	420
	10	495
	13	471
Shovun Lake	4	279
	6	425

1/ Peter Craig, LGL Ltd., Sydney, British Columbia, private communication. Fish were collected in 1972 and aged from otoliths.

Appendix Table 3. Depths and water quality measurements at Venetie Lake, 22 March 1982. The lake water at each site was organically stained.

Site #	Depth 1/ (m)	H_2S odor	Amphipods 2/	Comments 3/
1	1.75	strong	0	2.0 ppm D.O., 0.1°C
2	2.90	strong	0	0.1°C
3	2.70	strong	5	
4	2.20	strong	2-3	
5	2.40	strong	15-20	
6	2.25	strong	2	
7	2.30	weak	<1	
8	3.00	weak	0	
9	2.50	weak	0	
10	2.90	weak	0	0.5°C
11	2.70	weak	0	algae on underside of ice
12	2.70	strong	10	
13	3.02	weak	0	

1/ As measured from ice upper surface. Ice thickness was 1.1 m.
2/ Approximate number per liter of water brought to surface by the ice auger.
3/ D.O. is dissolved oxygen; temperatures are surface water temperatures in the ice hole.

Appendix Table 4. Sources of information on various water bodies in the Chandalar-Christian Rivers area. Numbers in parentheses in the location column are the number of sites at that general location. Numbers in parentheses in the type of data column are references explained at the bottom of the table.

Location	Type of Data
Ackerman Lake	Water quality, temperature and fish surveys (1,2,3)
Bearman Cabin, near Venetie	Historic fish distributions and utilization (3,4)
Big Creek, near Chandalar Lake	Stream sediment metal concentrations (5)
Big Fish Lake	Fish surveys (6,7)
Big Joe Creek, near Chandalar Lake	Stream sediment metal concentrations (5)
Big Lake, near Chandalar Lake	Water quality, temperature and fish surveys (1,2)
Blackfish Lake, near A.V.	Water quality, temperature and fish surveys (6)
Cane Creek (4), near A.V.	Water quality, benthic invert. and fish surveys (6)
	Fish surveys (8)
	Hydrologic surveys (9)
Chandalar Lake	Water quality, temperature and fish surveys (10,1,2)
Chandalar River at A.V.	Water quality, temperature and fish surveys (11,8,12)
Chandalar River at Chuttoh Bluffs	Water quality and quantity (13,14)
Chandalar River East Fork (4)	Water quality, temperature and fish surveys (6)
	Hydrologic surveys (9)

(continued)

Appendix Table 4. (Continued)

Location	Type of data
Chandalar River Unnamed Tributaries on East Fork (10)	Water quality, temperature and fish surveys (6,8,11) Hydrologic surveys (9)
Chandalar River Middle and North Forks	Fish surveys (1) Stream sediment metal concentrations (5)
Chandalar River at Venetie	Water quality (12)
Chandalar River Spring #1	Water temperature, water depths and pre-emergent chum salmon fry collection (15)
Chandalar River Spring #2	Fish surveys (16)
Christian River	Fish surveys and salmon escapements (17)
Deadman Creek, near A.V.	Water quality and fish surveys (6)
Gold Camp, at N. Fk. of the E. Fk. Chandalar River	Historic fish distribution and utilization (3)
Junjik Lake, near A.V.	Water quality, temperature and fish surveys (6)
Junjik River, (5) near A.V.	Water quality, temperature and fish surveys (6)
Little Squaw Creek, near Chandalar Lake	Stream sediment metal concentrations (5)
Loon Lake, A.V.	Water quality, temperature and fish near surveys (6)
Lower Fish Camp, near Suko	Historic fish distribution and utilization (18,3,4)
Lush Creek, near Big Rock Mtn.	Historical fish distribution (19)

(continued)

Appendix Table 4. (Continued)

Location	Type of data
Old John Lake	Water quality, temperature and fish surveys (2,6,7)
	Fish utilization (20)
Redfish Lake, near A.V.	Water quality, temperature and fish surveys (6)
Red Sheep Creek, near A.V.	Water quality and fish surveys (6)
Shovun Lake	Water temperature, lake depths and fish survey (15)
Squaw Creek, near Chandalar Lake	Stream sediment metal concentrations (5)
Squaw Lake, near Chandalar Lake	Water quality, temperature and fish surveys (10,1,2)
Spring Creek (2), near A.V.	Water quality, temperature and fish surveys (6)
Suko	Historic fish distribution and utilization (18,3)
Tobin Creek, near Chandalar Lake	Stream sediment metal concentrations (5)
Twentymile Lake	Historic fish distribution and utilization (3)
	Water temperature, D.O., depths and invertebrate sampling (15)
Twin Lakes, near Chandalar Lake	Water quality, temperature and fish surveys (1,2)
Unnamed Lake near Arctic Village National Guard Armory	Water temperature, D.O., and fish survey (6)
Unnamed Lakes near Cane Creek (8)	Water quality, temperature and fish surveys (6)

(continued)

Appendix Table 4. (Continued)

Location	Type of data
Unnamed Lake near Junjik River	Fish distribution (21)
Unnamed Lake, head-waters North Fork of the East Fork Chandalar River	Fish distribution (3)
Unnamed Tributary Squaw Lake	Stream sediment metal concentrations (5)
Unnamed Tributary Big Creek	Stream sediment metal concentrations (5)
Venetie Lake	Water temperature, D.O. and depths (15)
Vettatrin Lake, near A.V.	Water temperature and fish surveys (6)
Vunittsieh Lake, near A.V.	Water quality, temperature and fish surveys (1,2)

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Appendix Table 5. Water temperatures and water quality at springs identified in the CCR area. References are given in parentheses and are explained at the bottom of Appendix Table 4.

Name and Location	Date Surveyed	Temp. (°C)	Comments
Cane Creek #1 68°40'18"N 144°58'48"W	8/17/72 6/10/73 7/25/73		Several small springs located in the lower section of the creek contribute little flow during winter (6)
Cane Creek #2 68°41'10"N 145°3'36"W	7/25/73		"Small" spring located upstream of Cane Creek. Heavy algae cover (6)
Chandalar River Spring #1 67°1'17"N 146°32'24"W	3/23/82	1.2 to 2.3	In back slough of river 7 km upstream of Venetie. Approx. 100 m spring seep along gravel bank. Fall chum salmon spawning area (15)
Chandalar River Spring #2 67°5'34"N 146°57'00"W	9/82		Clearwater spring area in upper eastside tributary 25 km WNW of Venetie. Fall chum salmon observed spawning (16)
Deadman Creek Spring 68°15'48"N 145°40'48"W	4/7/73	2.0	D.O. 9.2 ppm, pH 8.0, hardneess 95 ppm, alkalinity 70 ppm, discharge 0.17 m^3/s, depth 38 cm (8)
EFCR Spring #1 68°37'43"N	5/18/72 5/24/73 144°55'12"W		Small upwelling between Red Sheep and Cane Creeks. Suspected RWF spawning and RWF and GR over-wintering site (8)
EFCR Spring #2 68°39'00"N 144°50'24"W	7/26/73	6.0	Springs located in a backwater downstream of Cane Creek (6)
EFCR Spring #3 68°53'35"N 144°17'24"W	7/28/73		Small spring (6)

(Continued)

Appendix Table 5. (Continued)

Name and Location	Date Surveyed	Temp. (°C)	Comments
EFCR Spring #4 68°37'30"N 144°50'24"W	6/24/72 5/28/73 6/29/73 7/28/73		Short mountain tributary of the EFCR. Several small spring sources present but no known over-wintering areas for fish (6)
Junjik R. Spring 68°24'00"N 145°55'12"W	6/24/72	9.0	D.O. 11.0, pH 8.5, hardness 188 ppm, alkalinity 154 ppm. Just below Spring Creek confluence. Aufeis 3.2 km downstream was 70 cm thick (6)
Red Sheep Creek 68°42'00"N 144°48'36"W	6/14/73	4.5	Spring-fed tributary flows into Red Sheep Creek near its mouth. Spring is the only known grayling spawning area upstream of Cane Creek (6)
Spring Creek 68°25'30"N 145°58'48"W	4/28/72		Several springs in lower section of creek.
Unnamed Lake Spring 68°44'22"N 144°48'00"W	6/14/73		Near Cane Creek. Water temp. of lake near spring was 9.5°C. Adult grayling and round whitefish caught by gillnet (6)

Appendix Table 6. Water temperatures in the Chandalar River at Venetie (U. S. Geological Survey 1968-1974).

Date	Temperature (^{o}C)
10 Sept 1971	4.0
12 Sept 1972	4.5
18 Sept 1968	5.0
20 Sept 1970	1.5
23 Sept 1967	1.5
24 Sept 1969	1.0
7 Mar 1970	0.0
13 Mar 1973	0.0
12 Apr 1972	0.0
29 Apr 1969	0.0
23 May 1967	2.0
29 May 1969	8.0
1 Jun 1968	2.0
7 Jun 1970	9.0
25 Jun 1971	16.5
28 Jun 1972	12.5
14 July 1970	11.0
9 Aug 1969	8.0
12 Aug 1971	11.0
12 Aug 1972	12.5
14 Aug 1970	13.0

Appendix Table 7. Water quality analysis, East Fork of the Chandalar River at Arctic Village, 17 May 1979 (Village Safe Water Program, Alaska Dept. of Environmental Conservation, Juneau).

VILLAGE SAFE WATER PROGRAM

TO BE COMPLETED BY SAMPLER

Sample Source or Location	Collected by
Pumphouse	John Thomas
Address	Sample Number: 6-JT-79

Village	State	Zip Code	Sample Date
Artic Village			5/17/79

300222

☐ Surface Water ☐ Ground Water enter as 5/18/79

☒ Untreated Water ☐ Treated Water

☒ Routine Sample ☐ Special Purpose Sample

Laboratory Analysis Number	Received by	Date
7905.3101	Sandra Paddock	5/30/79

	Limit	Mg/l
Arsenic	(0.05)	TR
Barium	(1.)	0.15
Cadmium	(0.010)	TR
Chromium	(0.05)	ND
Iron	(0.3)	0.90
Lead	(0.05)	ND
Manganese	(0.05)	0.28
Mercury	(0.002)	ND
Selenium	(0.01)	ND
Silver	(0.05)	ND
Sodium	(250)	.TR
Calcium		57.
Magnesium		1.7
Potassium		7.5

	Limit	Mg/l
Chloride		ND
Fluoride	(2.4)	TR
Nitrate	(10.)	TR
Sulfate		TR
Carbonate Alkalinity		160.
TFR		187.
pH		7.5
Turbidity		3.5 NTU
Color		30. PCU
Conductivity		290. µmhos/cm

ND=Not Detected
TR=Trace Detected

Date Analysis Completed	Signature of Laboratory Supervisor	Date Reported
6/21/79	T.C. Tnde	6/22/79

18-319(12/78)

Appendix Table 8. Water quality analysis, East Fork of the Chandalar River at Arctic Village, 6 June 1980 (Village Safe Water Program, Alaska Dept. of Environmental Conservation, Juneau).

20b VILLAGE SAFE WATER PROGRAM 1/23-pu

TO BE COMPLETED BY SAMPLER

Sample Source or Location: Chandalar River			Collected by: ~~XXXXXXXXXXX~~ John Thomas	
Address:			Sample Number: 28JT80	
Village: Arctic Village	State: Ak		Zip Code:	Sample Date: 6/6/80

- ☒ Surface Water
- ☐ Ground Water
- XX Untreated Water
- ☐ Treated Water
- XX Routine Sample
- ☐ Special Purpose Sample

Laboratory Analysis Number	Received by	Date
80061101	Parry Mothershead	6/11/80

	Limit	Mg/l
Arsenic	(0.05)	TR
Barium	(1.)	0.06
Cadmium	(0.010)	TR
Chromium	(0.05)	ND
Iron	(0.3)	2.7
Lead	(0.05)	0.006
Manganese	(0.05)	0.218
Mercury	(0.002)	ND
Selenium	(0.01)	ND
Silver	(0.05)	ND
Sodium	(250)	TR
Calcium		150.
Magnesium		5.7
Potassium		TR

ND=Not Detected

TR=Trace Detected

	Limit	Mg/l	
Chloride *			
Fluoride	(2.4)	TR	
** Nitrate – N	(10.)		
Sulfate		25.	
Carbonate Alkalinity		82.	
TFR @ 180° C		100.	
pH		7.8	
Turbidity		150.	NTU
Color		20.	PCU
Conductivity @ 25° C ***			μmhos/cm

** Note: Two "heavy metals" bottles received for the sample. Cannot analyse for nitrate due to acid rinse of bottle with HNO_3.

* Insufficient sample

*** Insufficient sample

Date Analysis Completed	Signature of Laboratory Supervisor	Date Reported
6/30/80	T.O. Tr[illegible]	7/1/80

18-319(12/78)

Appendix Table 9. Water quality analysis, East Fork of the Chandalar River at Arctic Village, 26 January 1981 (Village Safe Water Program, Alaska Dept. of Environmental Conservation, Juneau).

300230

VILLAGE SAFE WATER PROGRAM

TO BE COMPLETED BY SAMPLER

Sample Source or Location: School intake point		Collected by: Dan Easton	
Address:		Sample Number: 100 DE 81	
Village: Arctic Village,	State: AK	Zip Code: 99722	Sample Date: 1/26/81

☒ Surface Water ☐ Ground Water

☒ Untreated Water ☐ Treated Water

☐ Routine Sample ☒ Special Purpose Sample

Laboratory Analysis Number	Received by	Date
81021705	Wendy J. Whelan	2/17/81

	Limit	Mg/l
Arsenic	(0.05)	ND
Barium	(1.)	TR
Cadmium	(0.010)	TR
Chromium	(0.05)	TR
Iron	(0.3)	ND
Lead	(0.05)	ND
Manganese	(0.05)	TR
Mercury	(0.002)	ND
Selenium	(0.01)	TR
Silver	(0.05)	ND
Sodium	(250)	TR
Calcium		72.
Magnesium		7.0
Potassium		TR

	Limit	Mg/l
Chloride		ND
Fluoride	(2.4)	0.23
Nitrate — N	(10.)	TR
Sulfate		26.
Carbonate Alkalinity		147.
TFR @ 180° C		191

pH	8.2	
Turbidity	0.2	NTU
Color	10	PCU
Conductivity @ 25° C	320	µmhos/cm

ND=Not Detected

TR=Trace Detected

APR 1 0 1981

DEPT. OF ENVIRONMENTAL CONSERVATION

Date Analysis Completed	Signature of Laboratory Supervisor	Date Reported
4/15/81	T. C. [signature]	4/16/81

18-319(12/78)

Appendix Table 10. Water quality analysis, Chandalar River at Venetie, 6 July 1977 (Alaska Area Native Health Service, U.S. Public Health Service, Anchorage).

TELEPHONE (907) 279-4014 P.O.BOX 4-1276 ANCHORAGE, ALASKA 99509 4649 BUSINESS PARK BLVD.

JUL 25 1977

ANALYTICAL REPORT

Water Analysis(Facility) Alaska Area Native Health Service

Date Collected: July 6, 1977 Time Collected: --------- By: Rob Spring

Source of Sample: Venetie, Alaska. ~~Near~~ From slough near Post Office, Chandlar River.

Physical Observations, Remarks: Untreated, no smell or taste.

[]	mg/l	Aluminum	[X] 250	mmhos	Conductivity	[X] 120	mg/l	Hardness as $CaCO_3$
[X] <0.01	mg/l	Arsenic	[X] 7.8	units	pH	[X] 140	mg/l	Alkalinity as $CaCO_3$
[]	mg/l	Barium	[]	mg/l	Ammonia Nitrogen-N	[]	mg/l	Acidity-T as $CaCO_3$
[]	mg/l	Boron	[]	mg/l	Kjedahl Nitrogen-N	[]	mg/l	Acidity Free as $CaCO_3$
[]	mg/l	Cadmium	[]	mg/l	Organic Nitrogen-N	[]	/100ml	Coliform-T
[X] 38	mg/l	Calcium	[]	mg/l	Nitrate(N)	[]	/100ml	Coliform-F
[]	mg/l	Copper	[]	mg/l	Nitrite(N)	[]	/100ml	Strep-F
[]	mg/l	Chromium-Total	[]	mg/l	Phosphorus (Ortho)-P	[]	units	Color
[]	mg/l	Chromium-Tri	[]	mg/l	Phosphorus (Total)-P	[]		
[]	mg/l	Chromium-Hex	[X] <1	mg/l	Chloride	[]		
[X] <0.1	mg/l	Iron-Total	[]	mg/l	Fluoride			
[]	mg/l	Iron-Dissolved	[]	mg/l	Cyanide			
[]	mg/l	Lead	[X] 15	mg/l	Sulfate			
[X] 6	mg/l	Magnesium	[]	mg/l	Phenol			
[]	mg/l	Manganese	[]	mg/l	MBSA			
[X] <0.001	mg/l	Mercury	[]	mg/l	BOD			
[]	mg/l	Nickel	[]	mg/l	COD			
[X] 1.0	mg/l	Potassium	[X] 148	mg/l	TD Solids			
[]	mg/l	Selenium	[]	mg/l	FV Solids			
[X] 0.9	mg/l	Sodium	[]	mg/l	Suspended Solids			
[]	mg/l	Silver	[]	mg/l	SV Solids			
[]	mg/l	Zinc	[]	JTU	Turbidity			

Transported by:
Received by:

Transported by:
Received by:

FOR LAB USE ONLY

Lab# 6173 Rec'd by: Se

Date sample rec'd: July 7, 1977

Date analysis completed: 7-8-77

Date results reported: 7-8-77

Signed: Archie L. Bree

Date: July 11, 1977