PRELIMINARY INVESTIGATION OF CHUM SALMON SPAWNING IN KLUANE LAKE

Prepared for:

The Yukon River Panel
Restoration & Enhancement Fund
CRE-57-02

Prepared by:

Jane Wilson
J. Wilson & Associates
Box 20263
Whitehorse, Yukon
Y1A 7A2

On behalf of:

Kluane First Nation
Box 20
Burwash Landing, Yukon
YOB 1VO

April 2006

ABSTRACT

This report documents a chum salmon spawning site located at the southeast end of Kluane Lake near Silver City and provides preliminary information on the habitat characteristics of the site. At least 30 chum spawners were observed at this site during an aerial survey on October 14, 2002. Genetic material for stock identification was collected from 31 post-spawned chum.

Upwelling groundwater at this site is a critical hydrologic feature supporting a chum salmon spawning environment. During site investigations on October 27, 2002, groundwater was observed upwelling from gravels up to two meters from the water's edge and for approximately 135 meters along the shore. Upwelling could be inferred a distance of 30 meters from shore by the presence of air bubbles rising from depths of up to 1.6 meters. The geography of the lakeshore and its proximity to the fluvial environments of Silver and Outpost Creeks are the main controls on upwelling along this portion of the lake.

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INTRODUCTION

Fall chum spawning areas have been identified in rivers and side channels in the Yukon River drainage where upwelling groundwater is present. Although it has been suspected that fall chum may utilise lakes for spawning, this has not been previously documented in the Yukon River drainage. Since water temperatures are generally warmer where groundwater discharges, it has often been possible to predict available spawning habitat in shallow side channels or sloughs by looking for areas remaining open in the winter. In lakes, however, it is likely that upwelling areas would not be detected by open water in winter because of mixing of warmer groundwater with a large volume of cold water.

This report documents a chum salmon spawning site in Kluane Lake that has been reported by area residents. The objective of this study was to provide preliminary information on the habitat characteristics of this spawning area. These investigations may reveal particular features that could be used to distinguish other spawning areas in Kluane Lake and other lakes in the Yukon River drainage.

The specific study objectives are as follows:

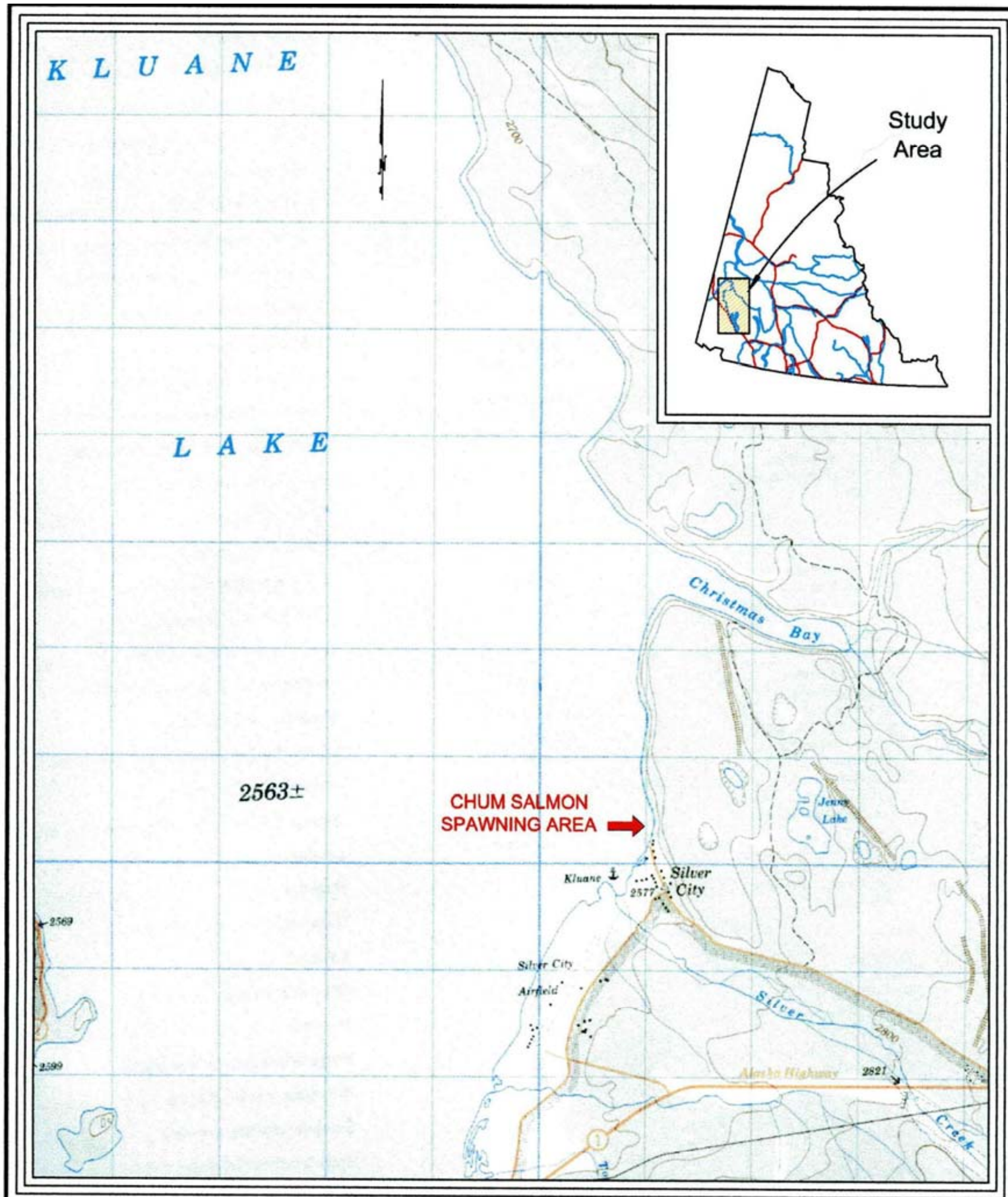
- Identify and characterise ground water sources.
- Describe geological features characteristic of this area.
- Determine extent of chum spawning habitat
- Collect tissue samples for DNA analysis.
- Retrieve spaghetti tags applied downstream for management purposes.

STUDY AREA

Kluane Lake is oriented in a southeast to northwest direction in the Shakwak valley in southwestern Yukon. Its drainage area includes tributaries in the Ruby Ranges and Kluane Ranges of the St. Elias Mountains. It is the largest lake fully contained within the Yukon Territory with a mean depth of 91 m and a surface area of 477 km^2 . The lake flows into Kluane River at the northwest end and is a major headwater lake in the White River sub-basin. The Alaska Highway follows most of the southern border along the western shore. The nearest communities are Destruction Bay and Burwash Landing, which are located along the western shore of the lake.

The study site is located at the southeast end of Kluane Lake between the outlets of Christmas Creek and Silver Creek, near the historic site of Silver City (Figure 1). A 'Bed & Breakfast' owned and operated by Doug and Cecile Sias is located in the vicinity of the chum spawning area.

A description of the glacial history and geomorphology of Kluane Lake's southeast end is given in Appendix 1.



CHUM SALMON SPAWNING AREA

SILVER CITY - KLUANE LAKE

FIGURE 1

SCALE 1:50,000

METHODS:

Chum salmon spawning survey

Run timing of chum salmon to the Kluane area was estimated from DFO in-season run timing data and from accounts by locals of spawning periods in previous years. Ground searches were conducted to determine the arrival of spawning chum salmon at the study site on the following dates: September 26, October 2 - 3, October 12 and October 22. Site investigations commenced on October 27. A delay of five days after the first chum sighting at this location was made to avoid disturbing spawning salmon.

In order to view salmon on redds without disturbing them, an underwater video camera was extended into the lake from shore on a long pole. Fish were then viewed from a video monitor placed on shore.

DNA tissue sampling

DNA tissue samples were collected from carcasses that had recently washed ashore and from live post-spawned chum captured in a gill net. All live fish captured were immediately sampled and then released. A small portion of tissue from the operculum of each fish was removed using a paper punch. Tissue samples were preserved in alcohol and sent to Pat Milligan, DFO stock assessment biologist, for analysis.

Sampled fish were examined for tags or tag scars and secondary marks applied at the time of tagging by DFO and USF&WS field personnel. Secondary marks included hole punches in the operculum (on fish tagged at the Canada/U.S. border) and left pelvic fin clips (on fish tagged at Rampart Rapids, Alaska).

Physical habitat characteristics

Several physical habitat characteristics were measured at the study site on October 27 in the lake and in upwelling ground water along the shore. Water quality variables including: water temperature, dissolved oxygen, conductivity, total dissolved solids (TDS) and pH, were measured in the lake close to the substrates at five meter intervals out from shore at two locations approximately 50 meters apart and on shore at a site where groundwater upwelled from gravels. Water temperature and conductivity measurements were also taken near substrates on a shoal located approximately 30 m from the shore. Water temperatures and dissolved oxygen were measured using an Oxyguard® Handy Beta Oxygen Meter calibrated to 94% saturation in air. Conductivity, TDS and pH were measured using a Hannah multi parameter meter. In addition, a water sample was collected from an undisturbed upwelling area on shore, preserved in 10% nitric acid, and sent to Norwest Laboratories in Burnaby B.C. for analysis of metals. Groundwater temperatures were also monitored continuously for one year using a temperature logger placed in a hole dug in the gravel on shore. Other information collected in the study area included substrate composition and depth of spawning. A depth sounder was used from a boat to measure redd depth in deeper areas that could not be accessed by wading.

RESULTS:

Chum salmon spawning survey

Chum salmon spawners were not seen at the study site until the October 22 ground search. Obtaining a total count of salmon in this area was not possible from shore or from a boat since they were extremely skittish when approached and would quickly move into deeper water where it was difficult to see them. During a helicopter survey conducted by DFO, at least 30 chum spawners were observed at this site on October 14, although viewing conditions were poor (Ferguson, pers. comm. 2002).

Biological sampling

A total of 31 chum salmon was sampled for genetic material. No spaghetti tags were observed on chum in the spawning area and no secondary marks or tag scars were observed on those examined.

Physical Habitat Characteristics

Upwelling Groundwater

Groundwater was observed upwelling from gravels up to two meters from the water's edge and for approximately 135 meters along the shore (Figure's 2&3). Upwelling was also inferred by the presence of air bubbles rising from a depth of 1.6 m at a site (station KL2) located 30 meters from shore.

Figure 2. Upwelling groundwater along lakeshore at chum salmon spawning site

Figure 3. View of shoreline at chum salmon spawning site looking west. Groundwater upwelling was observed along shoreline in area delineated.

Lake bottom water temperatures in the zone of upwelling varied from 3.6°C to 5.7°C (Table 1). A temperature of 4.1°C was recorded in an upwelling groundwater area on shore. Groundwater temperatures measured continuously for one year are shown in Figure 4. Unfortunately, temperatures recorded during this time indicated that water levels had dropped below the level of the temperature logger on or around February 20 exposing it to freezing temperatures. It appears that water levels did not rise and totally submerge the logger again until June 19, after which temperatures remained around 4.0°C.

Conductivity measurements taken in the zone of upwelling varied considerably from a low of 280 us/cm to a high of 940uS/cm (Table 1). Generally, conductivity measurements were highest in shallow areas close to shore and in upwelling groundwater on shore. The chemical analysis of a groundwater sample is provided in Appendix 1.

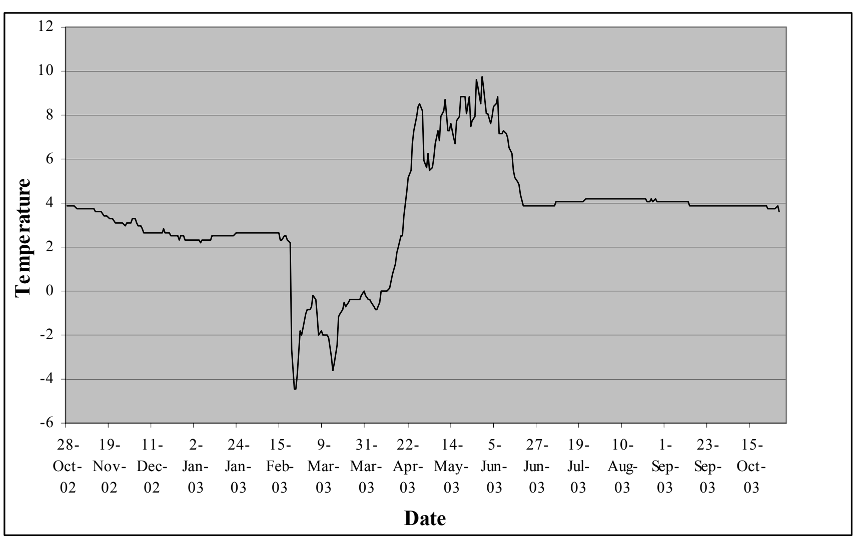


Figure 4. Daily temperatures of upwelling groundwater at chum salmon spawning site recorded for one year. Note sudden decrease in temperature after groundwater dropped below the level of the temperature logger.

Table 1. Field Measurements of Water Quality, October 27, 2002

Station	Distance from Shore (m)	Water Depth (cm)	Water Temp. (C°)	Dissolved Oxygen		Conductivity (us/cm)	Total Dissolved Solids (mg/l)	pH
				(ppm)	(%sat.)			
KL1	On shore *	--	4.1	9.2	69	940	432	7.5
	5	23	5.5	10.8	82	452	205	7.6
	10	40	4.8	11.7	89	415	190	7.8
	15	60	5.3	12.0	93	280	128	7.8
KL2	5	20	3.6	10.4	77	880	408	6.9
	10	43	5.7	11.9	93	304	141	7.4
	15	68	5.6	11.9	93	292	138	7.8
KL3	30	160	6.1	--	--	341	--	--

* groundwater upwelling on shore
Note: Water quality measurements in lake were taken immediately above lake substrates.

Substrate composition and redds

The lake shoreline in the study area consisted of cobble overlying gravels. This composition of substrates extended at least 20 meters into the lake at the current water level. Beyond this, the gradient increased and lake bottom substrates were covered with sediments, which are likely deposited by the Slims River current (see Figure 1 in Appendix 1).

Spawning redds were observed along the zone of upwelling groundwater at least 10 meters from shore in clean cobble/gravel substrates and approximately 30 meters from shore on a gravel bar overlain with silt. The water depth at these distances varied from 43 to 68 cm at the current lake level. Generally, redds were not well defined and were distinguishable only as irregular shaped areas where the larger cobble was randomly displaced and the smaller gravels exposed (Figure 5). The characteristic oval shaped mound and pit formation created by chum during redd development in side channels or sloughs in the Yukon drainage was not observed here (Figure 6). Similarly, redds observed on the silt laden gravel bar showed no mound development and were distinguishable as circular areas cleared of silt exposing ‘pea-sized’ gravels and sparse cobble.

Figure 5.   Substrates at chum spawning site in zone of upwelling groundwater. Patches of exposed gravels indicate a spawning redd.

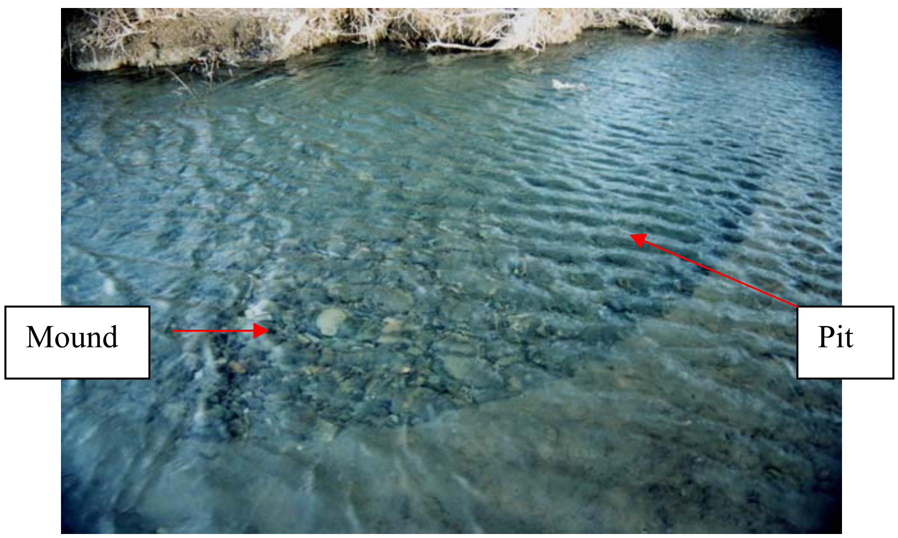


Figure 6. View of a chum salmon redd in spawning slough on the Kluane River. Note oval shaped clearing as a result of redd development.

DISCUSSION

It is generally accepted that fall chum salmon in the Yukon River drainage spawn in areas associated with groundwater upwelling where intragravel temperatures remain around 4°C (Maclean, 2001; Milligan et al., 1986). Since fall chum salmon spawn late in the season (September-November), a warm, thermally stable intragravel environment would support an egg to fry development rate that would result in advantageous emergence and downstream migration timing. Groundwater upwelling at the toe of the Silver and Outpost creek alluvial fan complex is one of the critical conditions supporting a chum salmon spawning environment in Kluane Lake.

Groundwater upwelling at this site could potentially emanate from Silver and Outpost creeks and/or down the Christmas Creek valley. Conductivity/TDS values measured at the site were moderately to very high which could imply a long flow path or a long duration underground. Although the depth of circulation of groundwater beneath the Silver/Outpost fan-delta is uncertain, quaternary deposits that fill the Shakwak Trench likely reach depths exceeding 300 metres (Bond, 2002). The proximity to the vigorous fluvial environments of Silver and Outpost creeks, strongly suggests that this is, at least in part, the source of upwelling groundwater along this portion of the lake (Bond, 2002) however this has not been confirmed.

The intention of this study was to provide preliminary information on some of the habitat characteristics of a chum spawning area in a lake environment. Further studies should be conducted on the physical and biological requirements for reproductive success in a lake environment to gain a better understanding of the environmental factors that could limit chum production.

The recommendations of this report are as follows:

- The collection of genetic material should be continued to meet the target sample size of 200 required for analysis. This could determine if chum salmon that spawn in Kluane Lake are genetically distinct from the Kluane River stocks. These samples, along with others collected in the Kluane River sub-basin would enable managers to identify and quantify Kluane area stocks in mixed stock fisheries and estimate timing of entry and run-timing patterns.

- Multiple studies of the freshwater life stages of chum salmon in a lake environment should be conducted. Investigations should include overwintering requirements, survival rates from egg to fry stage, out-migration timing and feeding behaviour.

- Investigations of the groundwater source and flow paths should be conducted including depth and magnitude of flow and water quality.

- Potential chum salmon spawning areas should be investigated near other creek outlets and alluvial fan complexes in Kluane Lake.

ACKNOWLEDGMENTS

The author would like to thank Edward Johnson, Grace Cohoe, Brad Wilson, Bonnie Burns, Kirk Johnson and Jeremiah Johnson for their assistance in the field. A special thanks is extended to Jeffery Bond, Yukon Geological Survey of Canada, Whitehorse, for providing geological information relevant to the study site. Thanks also to Doug and Cecile Sias and Frank and Josie Sias for extending kind hospitality during our visits to the study site.

The Yukon River Panel Salmon Restoration & Enhancement Fund under the U.S./Canada Interim Agreement of the Pacific Salmon Treaty provided funding for this project.

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Rick Ferguson, Senior Technician, Stock Assessment Division, DFO, Whitehorse, Yukon. personal communication, 2002.

Appendix 1. Dissolved Metals Analysed – Sample taken of groundwater upwelling from gravels on shore of Kluane Lake (KL1).

Metal	Level (mg/l)	Metal	Level (mg/l)	Metal	Level (mg/l)
Aluminum	<0.005	Iron	<0.1	Silver	<0.0001
Antimony	<0.0002	Lead	<0.0001	Sodium	4.0
Arsenic	<0.0002	Lithium	0.003	Strontium	1.09
Barium	0.015	Magnesium	39.3	Sulphur	113
Beryllium	<0.0001	Manganese	<0.005	Thallium	<0.00005
Bismuth	<0.0005	Molybdenum	0.001	Titanium	<0.0041
Boron	0.022	Nickel	<0.0005	Uranium	0.0015
Cadmium	<0.00001	Phosphorus	<0.03	Vanadium	0.0001
Calcium	133	Potassium	3.5	Zinc	0.001
Chromium	<0.0005	Selenium	0.004	Zirconium	<0.001
Cobalt	<0.0001	Silicon	3.26		
Copper	<0.001				

Appendix 2. Glacial History and Geomorphology of Kluane Lake's Southeast End

Prepared by: Jeffery Bond, Yukon Geological Survey of Canada, Whitehorse, Yukon.

Late Pleistocene glacial history

Glacial maximum

Thick glaciofluvial deposits and a large fan-delta originating from Silver and Outpost creeks characterize the geomorphology of the Kluane Lake's southeast end. During the height of the McConnell glaciation around 20,000 years ago a large northwest flowing valley glacier occupied the Shakwak Trench (Denton and Stuiver, 1967). The orientation of streamlined till blankets near Christmas Creek gives evidence to the northwest flowing glacier (Fig. 1). A tributary glacier emanating from the Slims River valley merged with the Shakwak ice mass in this vicinity.

Deglaciation

During deglaciation the ice became progressively thinner. Flights of well preserved meltwater channels near Outpost Creek indicate an abundance of meltwater trapped against the margin of the glacier (Fig. 1). Much of this meltwater is likely derived from the retreating alpine glaciers at the headwaters of Silver and Outpost creeks. At some point during the later stages of glacial recession the ice fronts from the Shakwak valley glacier and the Slims River glacier abut at the southeast end of Kluane Lake. This period may mark a re-advance of the glaciers or a temporary pause in their recession. Regardless, for a length of time a glacial terminus was located where Silver and Outpost creeks empty into the Shakwak Trench. A glacial terminus is an environment of relatively thin ice with numerous crevasses and sub-glacial cavities. Water and sediment draining Silver Creek flowed readily under and over the Shakwak glacier. This developed the esker swarm and crevasse fillings that trend nearly parallel with the present lakeshore labeled as a glaciofluvial complex in Figure 1. The sub-glacial streams did not flow directly towards the lowest ground, which is the area now occupied by Kluane Lake, because this lower ground was likely filled by a Slims River glacier. The steep front to the glaciofluvial complex along Kluane Lake is assumed to mark the abutment between the two glaciers. Hence the glaciofluvial complex can be defined as a kame deposit. The stagnation of Shakwak ice in this location is also evidenced by the large kettle depressions marking the location of former stranded ice blocks within the complex.

Holocene alluvial history

Upon retreat of the two glaciers from this area Silver and Outpost creeks were able to carve a course towards Kluane Lake. During this period a large area of the glaciofluvial complex was reworked into a fan-delta. Erosion continued up into the Silver Creek and Outpost Creek drainages, accessing large volumes of glacial sediment that was eroded and then deposited in the alluvial fan-delta (Fig. 2). The alluvial fan-delta continues to agrade into Kluane Lake as a result of the on-going erosion in these drainages.

Groundwater

Groundwater flow within this environment is expected to be high. Silver and Outpost creeks have high seasonal discharges and large volumes of this water seeps into the porous streambed, particularly on the upper reaches of the fan-delta. Within the fan-delta the ground water would flow towards Kluane Lake and surface at the fan-delta's distant margins, shown as dashed line B on figure 1. The upwelling both on-shore and offshore at the toe of the fan-delta is a function of the hydrostatic head created by the elevation change between the fan apexes and the lakeshore. A semi-impermeable glaciolacustrine clay layer at depth in the valley bottom may assist upwelling. However, this has not been confirmed. Within the glaciofluvial complex kettle lakes respond to water levels in Kluane Lake (Johnson, pers. comm., 2003). This lateral permeability with the glaciofluvial complex means it should also be subjected to the water pressures developed within the adjacent fan-delta. This would permit the zone of up-welling to extend northward along the front of the glaciofluvial complex (see C, Fig. 1). The transmissibility of water through the glaciofluvial complex may also be aided by the paleo-northward trend of channels within the complex as suggested by the orientation of eskers on the surface.

The zone of upwelling that occurs off shore along Kluane Lake is apparent in Figure 1. The dashed line labeled A follows a distinct mixing zone between the silt ladened waters of the Slims River current and the cleaner waters derived from ground water upwelling along the toe of the fan-delta. The upwelling, in combination with surface flow off the this fan, is at least partially diverting or diluting the Slims River current that flows along the toe of the fan.

The depth of circulation of groundwater beneath the fan-delta is uncertain. Quaternary deposits that fill the Shakwak Trench likely reach depths exceeding 300 metres. Circulation of groundwater to this depth would have a considerable affect on water temperature. This is supported by ground water temperatures of approximately 12 degrees Celsius recorded from a well in Haines Junction that extended to approximately 275 metres in depth (Pearson, Pers. Comm., 2002).

References:

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Personal communication:

Peter Johnson, Professor, Department of Geography, University of Ottawa

Forest Pearson, Geological Engineer, Gartner-Lee Ltd., Whitehorse, Yukon

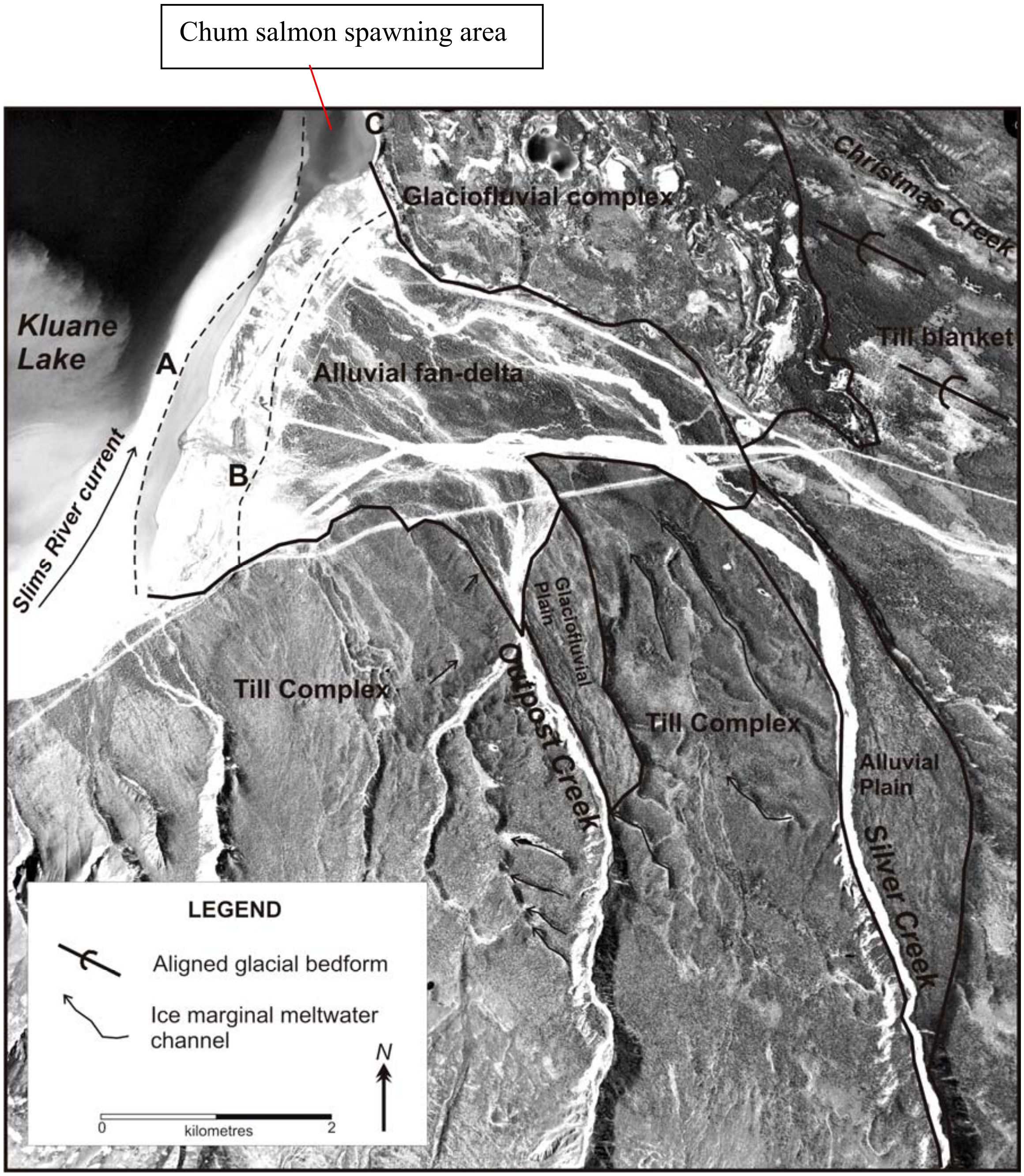

Figure 1. Annotated air photograph (NAPL A27478-85) showing geomorphic features at the southeast end of Kluane Lake. Outpost and Silver creeks originate in the Kluane Ranges immediately to the south.

Figure 2. A view to the north of the west bank of Silver Creek approximately 3 km upstream from the Alaska Highway. This exposure is approximately 25 m thick and consists of till and outwash gravel derived from the last glaciation and possibly sediment related to a middle Pleistocene glaciation. The incision by Silver Creek into this drift package has occurred since the late stages of the last glaciation and is on-going today.