1996 Fish Creek (Rat River, NT) Spring Reconnaissance

An Investigation of Dolly Varden Charr (*Salvelinus malma*)
Spawning and Overwintering Habitat

by

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and

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October 1996

Submitted to:

Gwich'in Renewable Resource Board (GRRB), Aklavik and Fort McPherson Renewable Resource Councils (RRCs), and the Department of Fisheries and Oceans (DFO)

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Summary:

Dolly Varden charr (*Salvelinus malma*) have been observed to spawn and overwinter in Fish Creek, a tributary of the Rat River, NT (Figure 1, Figure 4). An investigation of this tributary was conducted by snowmobile from April 2 to 4, 1996 and by helicopter on April 6 and May 17, 1996. The primary objectives of the research were to: 1. Locate areas of Fish Creek that could be used by charr for spawning; and, 2. Identify areas within the Rat River Drainage Basin that are used by anadromous (sea-run) charr for overwintering.

Three large areas of open water were located above the ice field (Aufeis field) on Fish Creek (Figure 7). All three areas were located some distance apart and well upstream of the stretch of river surveyed in the fall of 1995. Significantly greater volume and velocity of water and length of habitat were observed in Fish Creek than that found in similar habitats in either the Babbage or Big Fish Rivers. As a consequence, the Fish Creek site may be able to physically accommodate a larger number of spawning and non-spawning charr than either of the previously mentioned charr systems.

The temperature of the water in the discharge area in Fish Creek was found to be considerably cooler than that at other charr spawning and overwintering sites on the Yukon North Slope. This finding would support previous observations that this stock appears to spawn earlier (e.g., late August rather than late September) than other charr stocks along the Yukon North Slope. If so, the earlier spawning period may be a positive factor for the future management of the Rat River charr stock because spawning charr likely have to move upstream considerably earlier (probably mid to late July) than non-spawning charr. Consequently, they will be less likely to be caught by subsistence fisheries along Husky Channel and the lower Rat River, which tend to start in early to mid August. In addition, the shorter summer feeding period for spawning charr may result in a less extensive migration within coastal waters. This would reduce the chance of them being caught by fisheries operating along the coast (e.g., Shingle Point). These hypotheses are supported by 1995 harvest monitoring data which indicated that the majority of charr caught in 1995 were non-spawners. If spawning does occur in August then spawning activity, and possibly spawning success, may be affected by fluctuating water levels which occur at this time of year due to rainfall. An understanding of when, and under what conditions, spawning occurs in the Rat River could prove useful in the future management of the stock.

Charr and grayling were documented using the pool just upstream of the ice field on Fish Creek for overwintering (Figure 8). Both juvenile and adult charr and grayling were observed to be flushed from under the ice by water that upwelled through the hole drilled in this pool. Because more holes could not be drilled without the chance of water upwelling through a hole, the location and extent of overwintering habitat at the main site on Fish Creek was not determined. It is likely, however, that charr use the stretch of river from the 'fish pits' to the ice field for overwintering. This area was examined during the fall of 1995 and found to contain several large deep pools. Radio telemetry data gathered in the summer and fall of 1996 on the location of non-spawning charr in the Rat River drainage basin may help to support this hypothesis.

Recommendations for further research:

- Determining the timing of spawning for the charr stock in the Rat River may prove useful in its future management.
- The stretch of stream from Area 1 to the ice field (Figure 7) should be mapped and

surveyed in the summer or fall when the course of the river can be easily determined.

- Seining efforts in the fall should be expanded to include the upper section of Fish Creek (i.e., Area 1 to the ice field) if fish are observed in this region.
- Substrate in and near Area 1, Area 2, and Area 3 should be examined in the fall for the presence of eggs.

Acknowledgements:

We would like to thank Richard Francis and James MacDonald Sr. from Fort McPherson and Aklavik, respectively, for guiding and assisting with the snowmobile reconnaissance. We would also like to thank Doug Chiperzak (DFO.), Johnny Charlie Sr. (Fort McPherson), Richard Francis (Fort McPherson) and Kevin Mitchner (Canadian Helicopters) for their help with the May helicopter trip to the Fish Creek site.

Funding for this project was provided by GRRB and DFO.

Introduction:

Charr stocks to the west of the Mackenzie Delta spawn and overwinter (for eight to nine months) in a region of a headwater tributary, of their respective systems, that remains unfrozen throughout the winter due to the presence of a thermal spring(s) (Figure 1). A thermal spring is an area where water comes out of the ground, year round, at a temperature that is higher than that of the surrounding surface water. The area where the water comes out of the ground is referred to as the discharge or upwelling area. The stretch of stream associated with the discharge areas, which contain water throughout the winter, typically vary from 1-4 km in length. As the majority of these rivers, that support charr stocks west of the Mackenzie Delta, are generally shallow (0.5-1.0 m deep) and almost completely freeze to the bottom in the winter, the discharge areas offer the only available habitat within the system for charr to use for spawning, rearing, and overwintering. For Dolly Varden charr stocks along the North Slope, the general understanding of the location of these life history activities is that spawning occurs on or near the area of groundwater discharge and overwintering occurs some distance below this area, nearer the downstream limit of the site (McCart 1980, Craig 1989).

The specific area of groundwater discharge is probably selected by charr for spawning for a number of reasons including: 1) Eggs will not come in contact with ice because ice formation down to the bottom is prevented by the constant upwelling water; 2) Areas of upwelling are less likely to dry out during freeze-up than habitat downstream when surface run-off, and thus stream flow, gradually diminish; 3) Eggs will be exposed to a relatively stable incubation environment which is critical for proper egg development; and, 4) The constant upward and then downstream movement of water ensures that wastes (e.g., carbon dioxide) produced by the developing eggs are carried away and do not build up to toxic levels.

The habitat downstream of the area of groundwater upwelling is probably used by sea-run adult and juvenile charr for overwintering because: 1) In the case of mature spawning adults, there is likely insufficient time after spawning and before complete freeze-up to safely move to other systems (e.g., Mackenzie Delta); 2) All charr in this stock were previous spawned and reared (for up to four years) in this area of the river prior to going to sea. Therefore it is the only instinctually known location to successfully spawn and overwinter; and 3) This habitat tends to be significantly cooler in temperature than the habitat in and around the area of groundwater discharge. Therefore, metabolic costs to the overwintering and likely fasting charr are reduced. Thus, both sea-run spawning and non-spawning charr will return to the place where they were hatched to spawn and/or to overwinter.

In general, thermal springs form when water from melting snow in the spring and rainfall in the summer enters the earth's crust in a region of land called the recharge area. Recharge areas can vary from several hundred square meters to several thousand square kilometres in size. Systems with large recharge areas generally have a greater volume of water upwelling at the discharge area(s) and flow through the system, from recharge to discharge area(s), is usually gravity-fed, since the recharge area tends to be higher in elevation than the discharge area(s). The deeper the water travels into the earth's crust, as it moves through the spring system, the warmer the water will be when it reaches the surface. During the winter, this water flows downstream from the discharge area along the main course of the stream. As it does, it slowly cools until it freezes at some point downstream. In general, spawning/overwintering site(s) are made up of three main areas in the winter: 1) Discharge area (top of site); 2) Main body (middle and lower areas of site); and, 3) Ice field (bottom of site) (Figure 2).

The discharge area is located at the upstream end of the site and is where the upwelling groundwater first reaches the surface. There is almost always an open stretch of warmer water in this area that may extend some distance downstream of the discharge area. This area is typically shallow at first, but deeper pools may be present further downstream and the margins of the stream may be partially frozen over, although the ice is usually thin. Another characteristic of the discharge area is that the gravel is usually covered in long strands of filamentous algae. Only freshwater juvenile life history stages of charr and grayling have been observed to occupy this region during the winter in either the Babbage or Big Fish Rivers (Sandstrom, unpublished data).

The main body of the site is that area of stream between the discharge area and the top of the ice field. It is usually nearly completely frozen over with ice which increases in thickness further downstream. Typically, the main body makes up approximately 3/4 of the total length of the site above the ice field. This section may contain deep pools (>1 m) as well as shallow riffles. The temperature of the water under the ice in this region is near 0°C.

The ice field at the bottom or downstream end of the site is an expansive field of layered ice, usually several kilometres in length, formed when the water flowing downstream disperses horizontally and freezes in consecutive layers. The top upstream end of the ice field usually marks the downstream limit of the overwintering site and the ice field itself is generally thought to be unoccupied by fish. However, overwintering juvenile and adult charr were caught in the ice field at the Big Fish River in tunnels that formed in the ice. Ice tunnels may be unique to this system due to the high discharge water temperature (Figure 3, Table 1).

The length of stream in which water is present at these spring-fed spawning and overwintering sites, during the winter, depends on a number of factors: 1) The temperature of upwelling water at the discharge area; 2) The gradient of the river (rise/run); 3) The exposure of the water surface to the elements; and, 4) The average minimum winter air temperature. Increasing factors 1 or 2 will tend to elongate the site as will decreasing factor 3. Lower winter air temperatures will result in a decrease in the volume of water available to charr by increasing the thickness of the ice. Because winters can vary in severity from year to year, so will the amount of habitat available to the overwintering charr stocks. If overwintering habitat is a limiting factor to these stocks, then in severe winters overwintering mortality rate may increase.

The Rat River, which flows a distance of approximately 100 km from its headwaters in the Richardson Mountains to it's mouth at Husky Channel, supports a stock of sea-run Dolly Varden charr (Figure 1). This population is known to spawn and overwinter in Fish Creek, a headwater tributary of the Rat River (Figure 1, Figure 4). However, very little is known, either from the scientific literature or local knowledge, about the specific location and size of the spawning and overwintering habitats for this charr stock. Because knowledge of critical habitats is important for the proper long-term management of the stock, a project was developed to identify the location of spawning and overwintering habitat in Fish Creek. Locating the area(s) of groundwater upwelling in these headwater tributaries is most easily done in the winter when there is no runoff and the area of the stream which is not under the direct influence of the upwelling water is frozen over. The primary objectives of the spring reconnaissance were to: 1) Locate the discharge area(s)in the Fish Creek tributary and thus identify areas which might be used for spawning; and, 2) Locate areas within the Rat River Drainage Basin that are used by anadromous charr for overwintering.

Methods:

A reconnaissance of the study area was made using snowmobiles on April 2 to 4, 1996. Two additional day trips were made to Fish Creek by helicopter on April 6 and May 17, 1996. Any large open (unfrozen) stretches of the stream that were free of surface ice were marked and measured. Substrate in some of these open areas was sampled using a small kick sampler to determine whether eggs were present (Figure 5). Water temperature and water chemistry samples were taken at the open water areas. Areas of open water in the site were also surveyed for the presence of juvenile and adult charr. An attempt was made to determine the location of overwintering habitat for anadromous charr by drilling holes through the ice using an auger in different areas of Fish Creek (Figure 6).

Results:

Three large (20 to 50 m long) stretches of open water were located and identified as Area 1, Area 2, and Area 3, respectively (Figure 7). All of the large stretches of open water were located upstream of where the seining survey began in 1995. An accurate measurement of the actual distance could not be taken in April as deep snow and areas of unfrozen stream made it difficult to follow the course of the stream directly. It is estimated that the top of the site (furthest upstream that open water was found) was approximately 4-5 km from the top of the stretch of stream surveyed in the fall 1995. Therefore, the total length of stream above the ice field on Fish Creek, that contains water during the winter, was between 5 and 6 km in length. The average width of the stream along the length of the site was approximately 2-3 m.

Area 1 (67°48'141", 136°17'852") (Figure 7) was the most upstream stretch of open water found on Fish Creek, and was located approximately 5.5 km above the ice field. The open water at Area 1 was about 15-20 m long, 2-3 m wide, and the majority was <10 cm deep. Water temperature and chemistry data were collected from this area (Table 1). Several deeper ice-covered pools, up to 0.75 m deep, were also found downstream and adjacent to this site. A stretch of stream, approximately 20-30 m immediately downstream of the open water at Area 1, appeared to be recently frozen over as the ice was only a few centimetres thick. This area may only freeze intermittently throughout the winter when the air temperature drops for an extended period of time. There was extensive development of long (>10 cm) strands of filamentous brown and green algae on the gravel in the shallow open water area. The dense mat of algae, shallow water, coarse gravel, and surface ice prevented kick sampling at Area 1 to determine whether eggs were present in the gravel. No juvenile or adult charr were observed in this area. Approximately 1.0 km upstream of this site and off the main channel of Fish Creek was a small ice field (approximately 50-60 m wide and 750 to 1000 m long) (Figure 7). No open water or flow was detected above this small ice field. Deep snow prevented a thorough investigation of the ice field.

Area 2 (67°48'6.2", 136°17'55.4") (Figure 7) also appeared to be near an area of groundwater discharge and was approximately 5 km above the ice field and 0.5 km downstream of Area 1 (Figure 7). Water temperature at this location was 1.5°C in April and 1.9°C in May. The open water at Area 2 was approximately 30-40 m long and 2-3 m wide. Flow was more substantial here than at Area 1 and the water was about 30 cm deep. A kick sample was conducted in a region that appeared to have gravel of suitable size for spawning. No juvenile or adult charr or eggs were found in the area of open water at Area 2. Algal growth at this location was limited during the April trip, but had developed into a dense layer by the May trip .

Area 3 (Figure 7) was not thoroughly examined, but is likely also near an area of upwelling water. It was located approximately 3 km above the ice field and 2.5 km downstream of Area 1. It consisted of a stretch of open water 50-60 m long, 2-3 m wide, and was a similar depth as that found at Area 2. From a brief inspection, Area 3 appeared to be unsuitable for spawning. No adult fish were observed in this area and no water samples were taken. A very small area of groundwater discharge was also documented approximately 2 km downstream of Area 3 (Figure 8). This upwelling was approximately 50 m outside of the main stream course and produced an area of open water of 1-2 km^2. Water depth was <5 cm (Figure 7).

Charr overwinter at Fish Creek, as charr and grayling (both juvenile and adult) were observed being flushed out from under the ice by water that upwelled through a 0.25 m diameter hole drilled approximately 100 m from the top of the ice field (Figure 7, Figure 8, Figure 9). The ice was 2.3 m thick at this location and there appeared to be approximately 0.5 m of water under the ice at this location. A total of 30 grayling were observed to be flushed out during the two days that the crew was on site. Eight of these were captured and released upstream at Area 2, eight were dead-sampled, and the remaining juvenile grayling were left in a large pool created by the upwelling. In addition, two or three young charr (likely two-year-olds), one post-smolt, and one resting adult were also observed to be flushed up and out through the hole. No upwelling movement of water or fish were detected in the vicinity of the hole on May 17, 1996. At the time the hole was drilled it was decided that no further drilling would be conducted to avoid the possibility of a similar upwelling of water through the ice in other areas of the site. Because holes could not be drilled in this site without the chance of causing some change in the flow, the location and extent of additional overwintering habitat at the main site on Fish Creek could not be identified.

Attempts to evaluate other areas for overwintering habitat were compromised by deep snow. An attempt to travel up Scho (locally known as "Sheep") Creek was made, but was unsuccessful. This Creek was shallow and did not have any fish when it was examined during the survey in fall 1995 (Harwood and Sandstrom 1996). Investigation of a unnamed lake near the confluence of Fish Creek and the Rat River noted in the fall 1995 research proposal was not undertaken.

Discussion:

Area 1 is probably the most upstream that groundwater discharges in the spawning and overwintering site on Fish Creek and thus, is likely the most upstream that anadromous spawning activity (and overwintering) could occur in this tributary. The reduced flow at Area 1 and the low discharge water temperature in this system may be responsible for the small area of open water at Area 1. Due to the relatively small volume of flow in Area 1, it is likely that this is not the only discharge area for the Fish Creek spawning and overwintering site. The large stretches of open water at Areas 2 and 3 are highly suggestive that some upwelling also occurs in these areas. The fact that water temperature was similar in Areas 1 and 2, which are separated by more than 0.5 km, tends to support this. If Area 1 was the sole discharge area for the main site the water temperature would have dropped by the time it reached Area 2.

Similar late-winter investigations of habitat have been conducted at other spring-fed spawning and overwintering sites on the Yukon North Slope. At the Babbage River, the discharge water temperature is 4°C and the area of water associated with it downstream is approximately 1.0-1.5 km long (Mutch and McCart 1974). At the Big Fish River, the discharge water temperature is approximately 15°C and the length of stream containing water in the winter is 3-4 km long (Mutch and McCart 1974). In comparison, the discharge water temperature at Fish Creek is approximately 2°C, however, the length of stream containing water is longer (5-6 km). Therefore, it appears that the Fish Creek site is unusually long in comparison to other charr systems given the temperature of the upwelling water. This is likely due to a combination of factors.

The air temperature regime during the winter is probably similar among the different spawning and overwintering sites west of the Mackenzie Delta due to their relatively close proximity. However, the volume and velocity of water at the site on Fish Creek was significantly greater, both in the fall and during the winter, than that found at the Babbage and Big Fish River sites (Sandstrom, unpublished data). Although the change in elevation (first upstream discharge site to the ice field) was not determined in any of the charr systems, the higher water velocity at the Fish Creek site is probably due to a greater change in elevation from the top to the bottom of the site. The steeper gradient could contribute to the longer site at Fish Creek as the faster flowing water will take longer to freeze.

Another factor which probably contributes to a longer site at Fish Creek, considering the discharge water temperature, is that there appears to be more than one area of groundwater discharge. As one moves downstream from Area 1, there is a noticeable increase in the volume of flow. This observation suggests that there are likely several springs discharging in spatial series along the 'upper' part the site. The longer site is produced when water flowing downstream is prevented from cooling to the point of freezing by the incoming warmer water from downstream discharge areas. In the process, the volume of water increases and this, combined with a greater velocity, elongates the site.

The presence of several areas of groundwater discharge within Fish Creek is a positive observation for the health of the stock. If spawning site selection and spawning success is dependent on the presence of upwelling groundwater then suitable spawning habitat may be extensive at the Fish Creek site. A larger spawning area means a greater number of eggs can be successfully incubated in the system, which in turn increases the number of juveniles and, ultimately, the number of adult fish in the stock. In addition, the presence of several discharge areas throughout the course of the main stream appears to produce a considerable amount (>5 km) of habitat that is available to both juvenile and adult charr for overwintering. This, combined with several very deep pools (1.5-2.0 m deep) that exist in the lower reaches of the overwintering site (Harwood and Sandstrom 1996), suggests that the availability of overwintering habitat is less of a constraining factor for this charr stock than it is for other charr stocks along the Yukon North Slope.

The large volume and cooler water temperature at the spring discharge sites indicates that the spring itself is a shallow rapid flow system with a large recharge area. The low water temperature at the upwelling sites would support the observation made by past researchers (e.g., Jessop et al. 1973) that the Rat River charr stock appears to spawn earlier than other Yukon North Slope charr stocks (late August rather than late September). For most species of fish, lowering the water temperature will lengthen the duration of egg incubation. Hatch and later emergence of charr fry from the gravel is typically timed with the spring break-up in mid to late May (McCart 1980). Therefore, spawning in these stocks must occur at the appropriate time in the fall for emergence to take place at the right time in the spring and this will be dependent on the temperature regime to which the eggs are exposed. For the Fish Creek site, where incubation temperatures are cooler than those found at the Babbage or Big Fish River sites, spawning will likely need to be earlier to compensate for a longer incubation period. Hatfield et al. (1972) reported observing spawning behaviour in Fish Creek during the August surveys. Jessop et al. (1973) reported that spawning was observed in Fish Creek on August 18, 1971 and by September 19, all mature (current year spawners) charr had spawned. Similarly, all mature charr captured at the end of September, 1995 at the Fish Creek site were completely spent (Harwood and Sandstrom 1996). In comparison, in the Babbage and Big Fish Rivers, a large percentage (average 46%) of the samples taken at the overwintering sites in early October were either partially spent or ripe (e.g., had not spawned) (Sandstrom 1995). These observations suggest that spawning in the Fish Creek site does occur some time earlier than spawning in the Babbage and Big Fish Rivers.

If spawning occurs in August then this may be a positive factor for the future management of the Rat River charr stock. Spawners will likely be moving upstream considerably earlier, perhaps as early as mid July, than non-spawners and are therefore less likely to be caught by subsistence fisheries along Husky Channel and the lower Rat River (Figure 1) that usually start in mid August. In addition, because the summer feeding period will be shorter for spawning charr from the Rat River, their downstream migrations may not be as extensive as those of the non-spawners. This would reduce the chance that charr from the Rat River would be caught by coastal fisheries (e.g., Shingle Point, Figure 1). These hypotheses are supported by 1995 harvest monitoring data which indicated that the majority of Rat River charr caught in subsistence fisheries were non-spawners (Harwood, unpublished data).

Conversely, spawning in mid to late August may impart a greater mortality on the eggs of Rat River charr in certain years. Water levels and current velocities are known to vary dramatically over the summer in charr systems west of the Mackenzie Delta. This is because the headwaters of these systems are situated in mountain ranges with steep relief and the area of land around the stream has permafrost and little vegetation. As a result they are quick discharge rivers, with water levels rising and falling quickly after a rain. In charr systems where spawning takes place later in the fall, after freeze-up starts (beginning of October), water levels and current velocities are usually nearing the minimum and remain relatively stable over the duration of the spawning period. In the Rat River, however, it may be possible that with heavy rains during the latter part of August, spawning could be hampered or delayed by high water levels and in the process increase egg mortality. This mortality could occur either in the fall, if spawning takes place during high water, or in the following spring, if spawning is delayed by high water. In the situation where spawning occurs during high water, fertilization success (%) would likely decrease as would the number of eggs that would be successfully buried by the female. If spawning is delayed by high water, then hatch and emergence of fry from the gravel would also be delayed. If these events are timed for a critical period in the spring then this may be missed by a delay in spawning the previous fall. Thus, because there is some evidence to suggest that spawning is earlier in the Rat River charr stock, an understanding of when and under what conditions this activity occurs in the stock would be of importance for its future management. For example, the monitoring of water levels may provide managers with advance warning of weak year classes in the fishery due to reduced level of recruitment in a particular year that experienced high water during the spawning period.

Holes drilled through the ice in similar locations and at similar times of the year, at the spawning and overwintering sites in the Big Fish and Babbage Rivers, to locate overwintering habitat, did not produce any upwelling water. The occurrence of this at the Fish Creek site is likely due to the greater volume and velocity of water flow in this system. The large volume of water that was easily diverted and forced up the 25 cm wide x 2.3 m deep drill hole suggests that the system may be operating under a positive water load. This means water is introduced upstream into the system faster than it can be frozen downstream in the area of the ice field. This creates a 'bottleneck' in the flow and likely some back pressure at the bottom of the system. Because holes could not be drilled in this site without the chance of some change in flow rate downstream, the extent and location of overwintering habitat could not be positively determined. It is likely that the lower reaches of Fish Creek above the ice field, which were found during the fall survey in 1995 to be made up of several large deep poles, are the location of the main overwintering sites (Harwood and Sandstrom 1996). This extends roughly from the area locally known as the "fish pits" (near the traditional fish hole) to the riffle areas above the ice field (Figure 7). Radio telemetry data gathered in the summer and fall of 1996 on the location of non-spawning charr in the Rat River drainage basin may help to support this hypothesis.

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Table 1. Water temperature and chemistry data collected from the spawning and overwintering sites on Fish Creek.

River	**Rat River**	Big Fish River	Babbage River
Location	**Fish Creek**	Cache Creek	Wood Creek
Sub-Location	**Area 1**	Pool below Falls	Falls Main Spring
Date	**03/04/96**	06/04/96	14/05/96
Temperature (°C)	**1.5**	10	4
pH	**8.61**	8.77	8.38
Conductance (umhos/cm @ 25°C)	**411**	3723	1372
Ca (mg/l)	**72.3**	117	43.8
Mg (mg/l)	**13.3**	24.8	10.8
Na (mg/l)	**4.7**	662	198
K (mg/l)	**0.59**	34	7
SO_4 (mg/l)	**96.6**	325	148.3
Cl (mg/l)	**2.1**	849	185.9
TDN[a] (µg/l)	**140**	420	-
TDP[b] (µg/l)	**4**	3	-
DIC[c] (µm/l)	**2650**	4550	1640
DOC[d] (µm/l)	**100**	100	570
Anions (µeq/l)	**4811**	36375	12707
Cations (µeq/l)	**4921**	37541	11865

[a] Total Dissolved Nitrate.
[b] Total Dissolve Phosphate.
[c] Dissolved Inorganic Carbon.
[d] Dissolved Organic Carbon.
- = data not recorded.

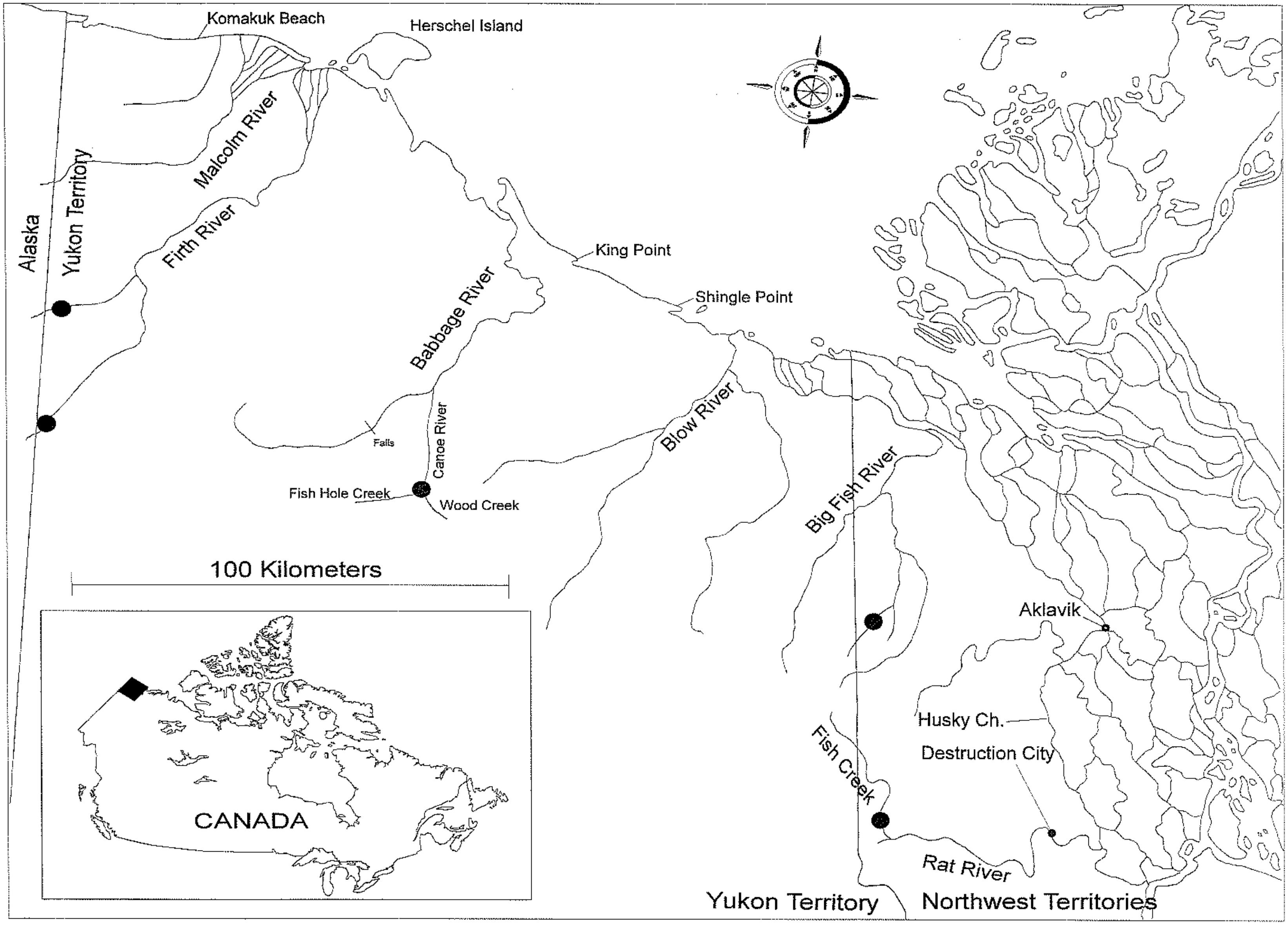


Figure 1. Map of the Yukon north slope showing the location known spawning and overwintering sites for Dolly Varden charr. The (●) denotes areas of groundwater discharge that are used for spawning and overwintering.

Figure 2. The main components of an overwintering site (Babbage River) (S. Sandstrom).

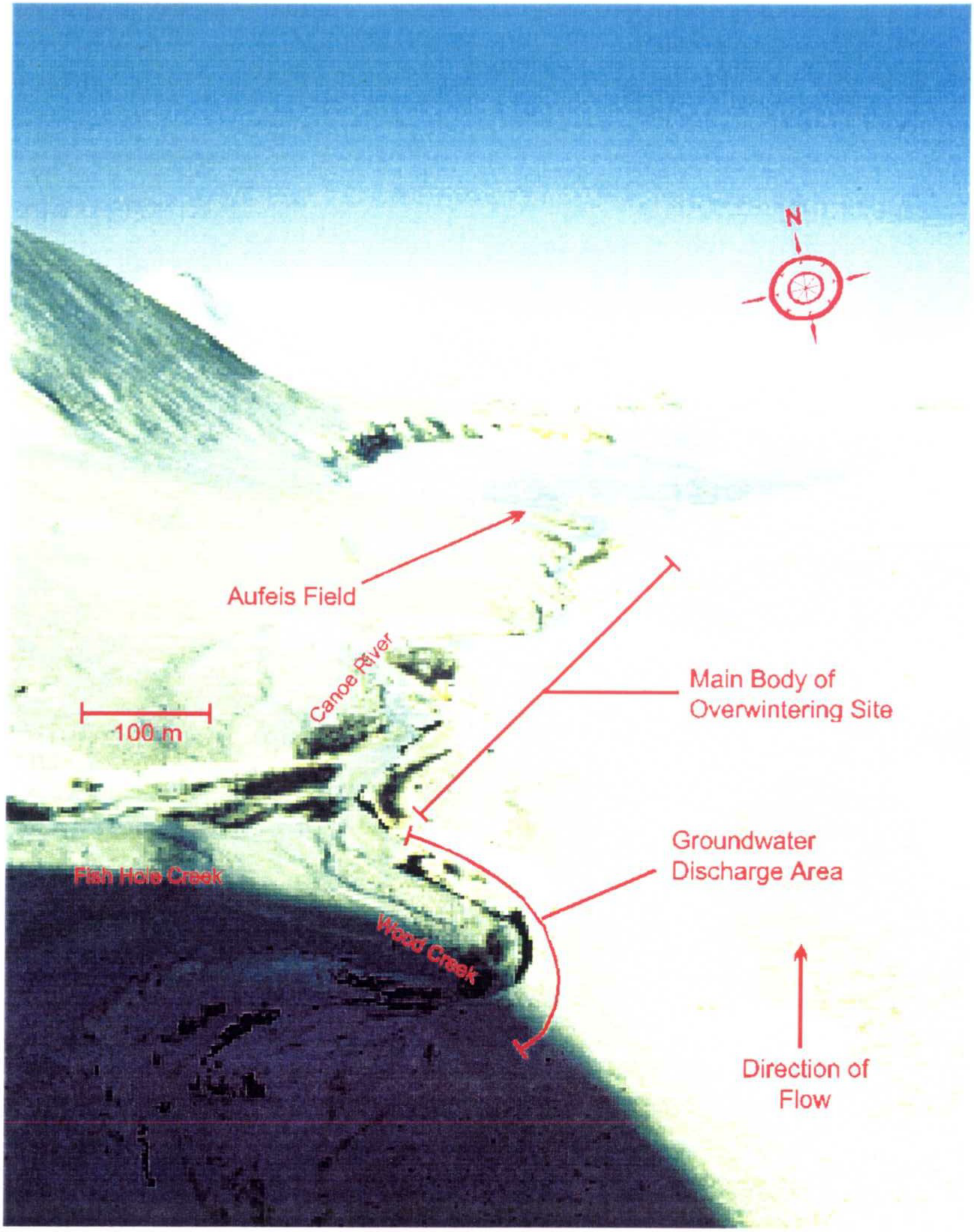

N
Aufeis Field
Canoe River
100 m
Main Body of
Overwintering Site
Fish Hole Creek
Groundwater
Discharge Area
Wood Creek
Direction of
Flow

Figure 3. Ice tunnels at the Big Fish River overwintering site (S. Sandstrom).

Figure 4. A northern, aerial view of Fish Creek, a tributary of the Rat River (September) (GRRB).

Figure 5. Richard Francis samples Area 2 on Fish Creek (S. Sandstrom).

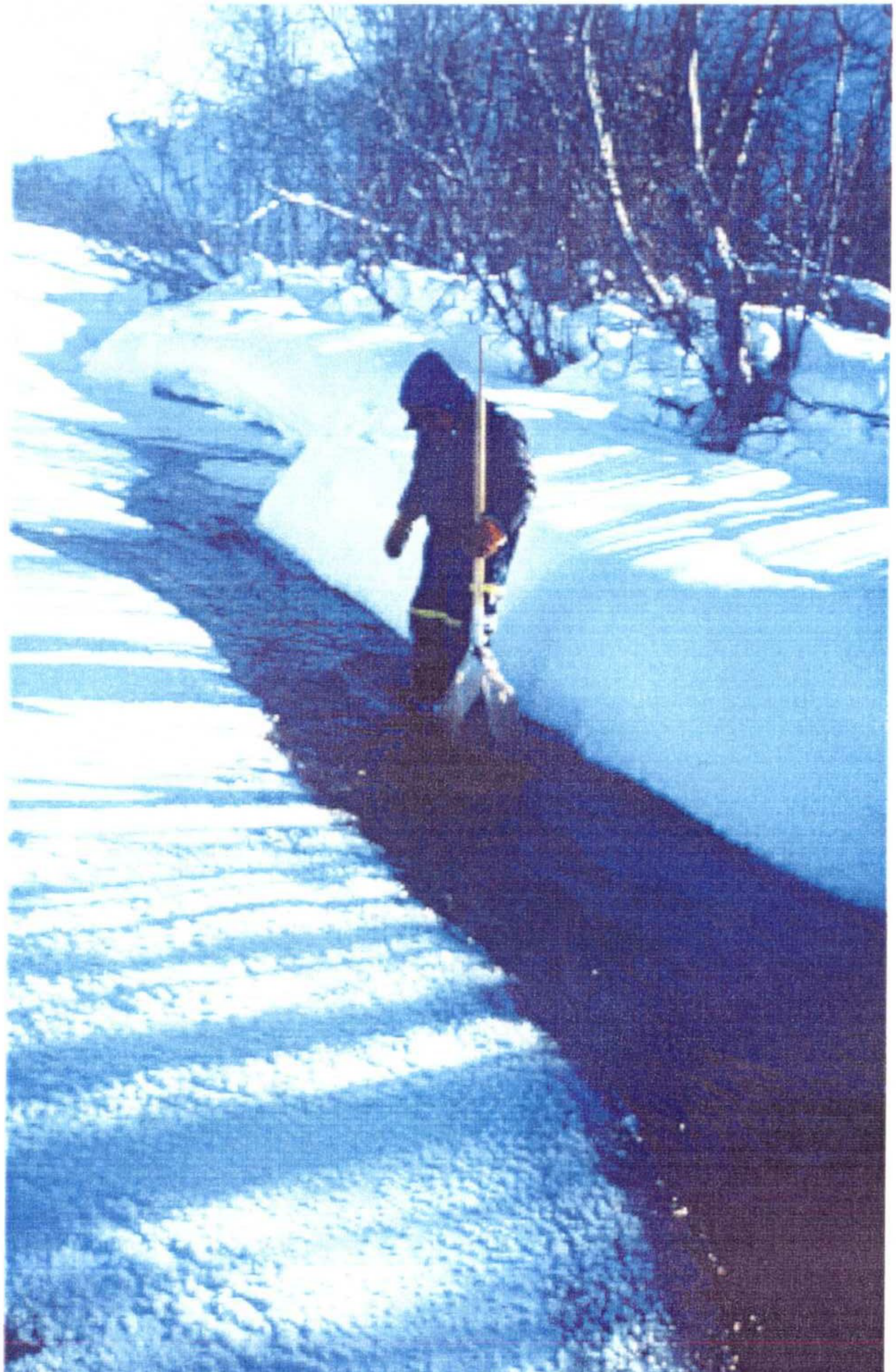


Figure 6. Richard Francis drills a hole above the ice field on Fish Creek (S. Sandstrom).

Figure 7. Sampling locations on Fish Creek.

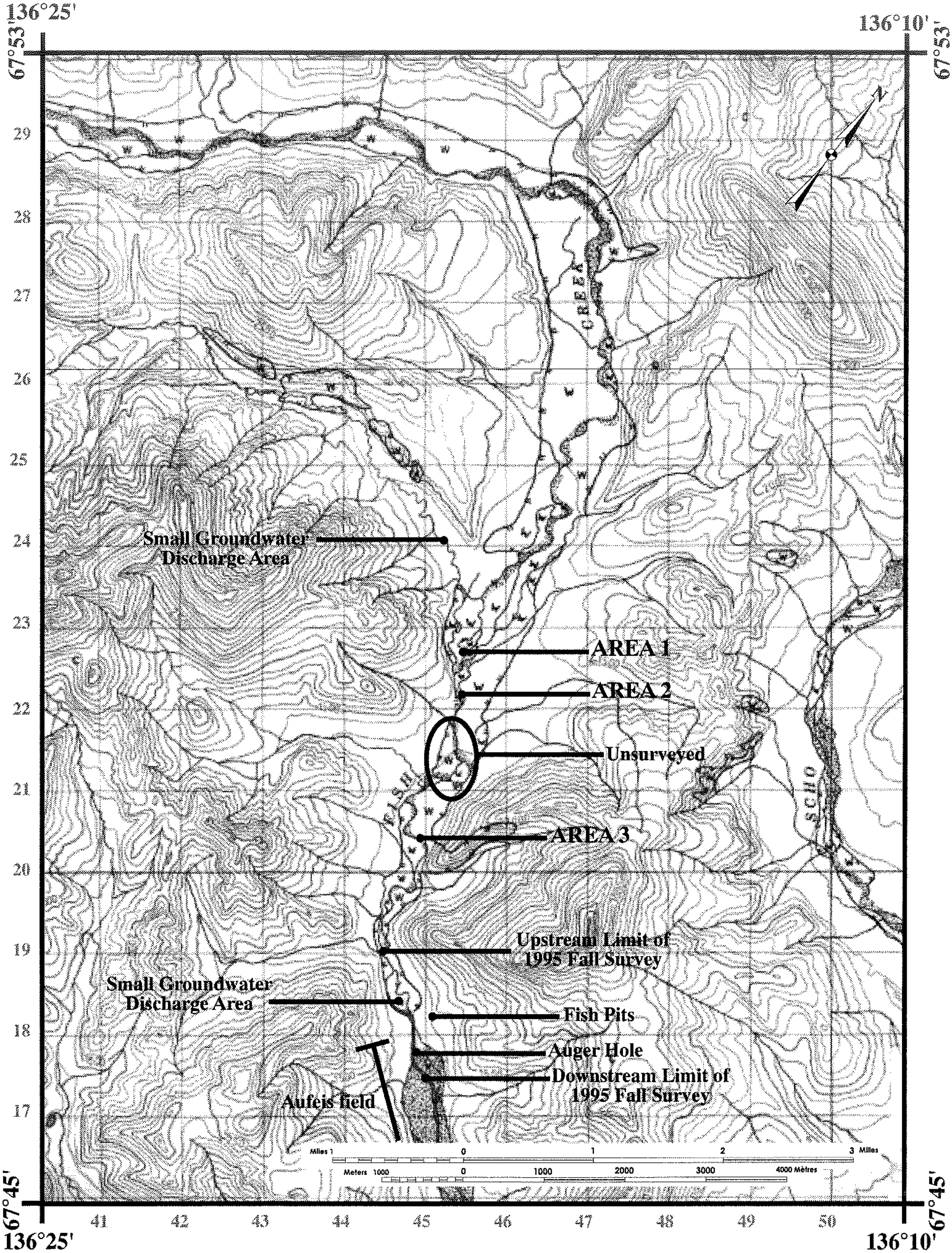

136°25'
136°10'
67°53'
67°45'
Small Groundwater Discharge Area
AREA 1
AREA 2
Unsurveyed
AREA 3
Upstream Limit of 1995 Fall Survey
Small Groundwater Discharge Area
Fish Pits
Auger Hole
Downstream Limit of 1995 Fall Survey
Aufeis field
CREEK
FISH
SCHO
Miles 1 0 1 2 3 Miles
Meters 1000 0 1000 2000 3000 4000 Mètres
41 42 43 44 45 46 47 48 49 50
29 28 27 26 25 24 23 22 21 20 19 18 17

Figure 8. Aerial view of the ice field on Fish Creek (April) (S. Sandstrom).

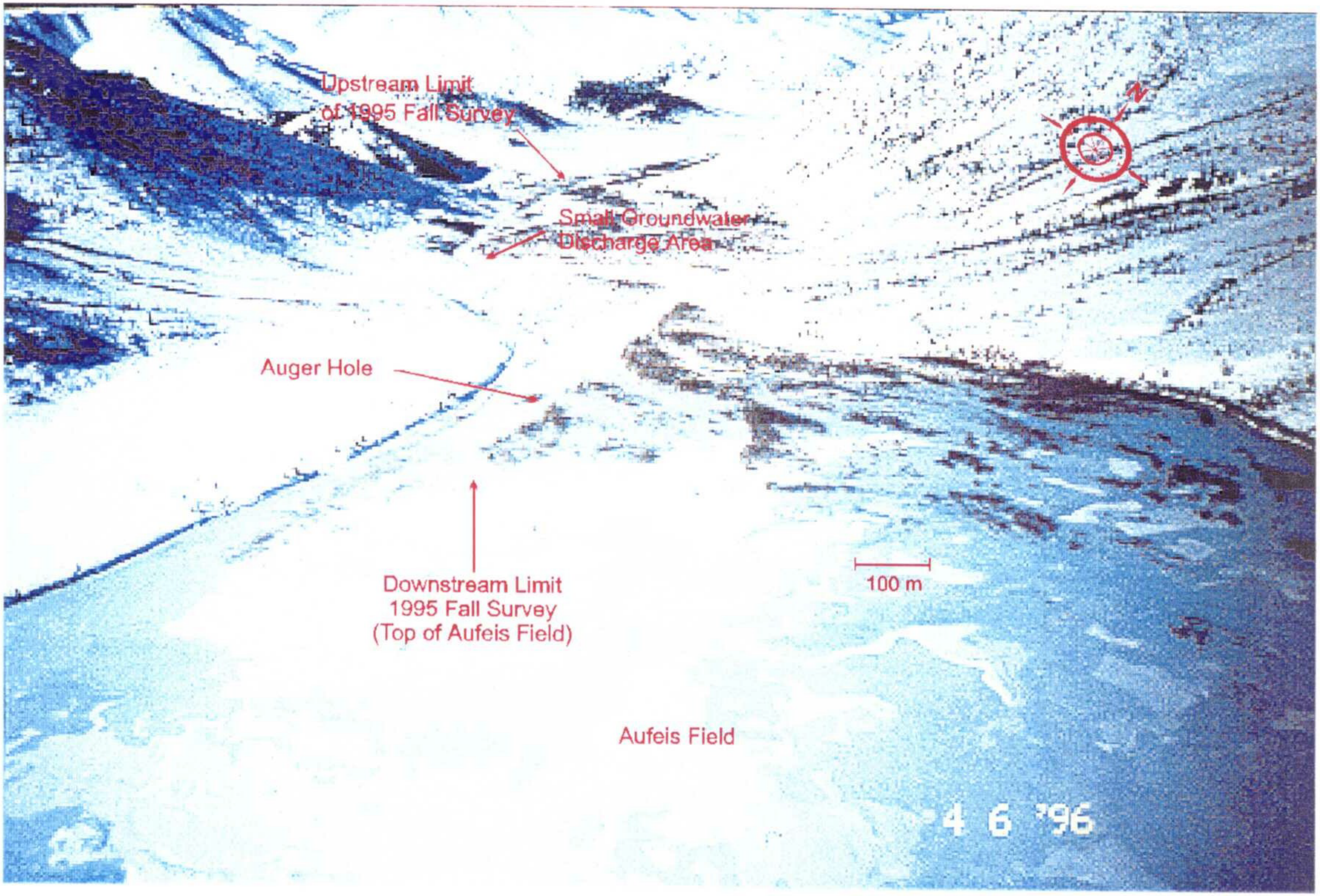
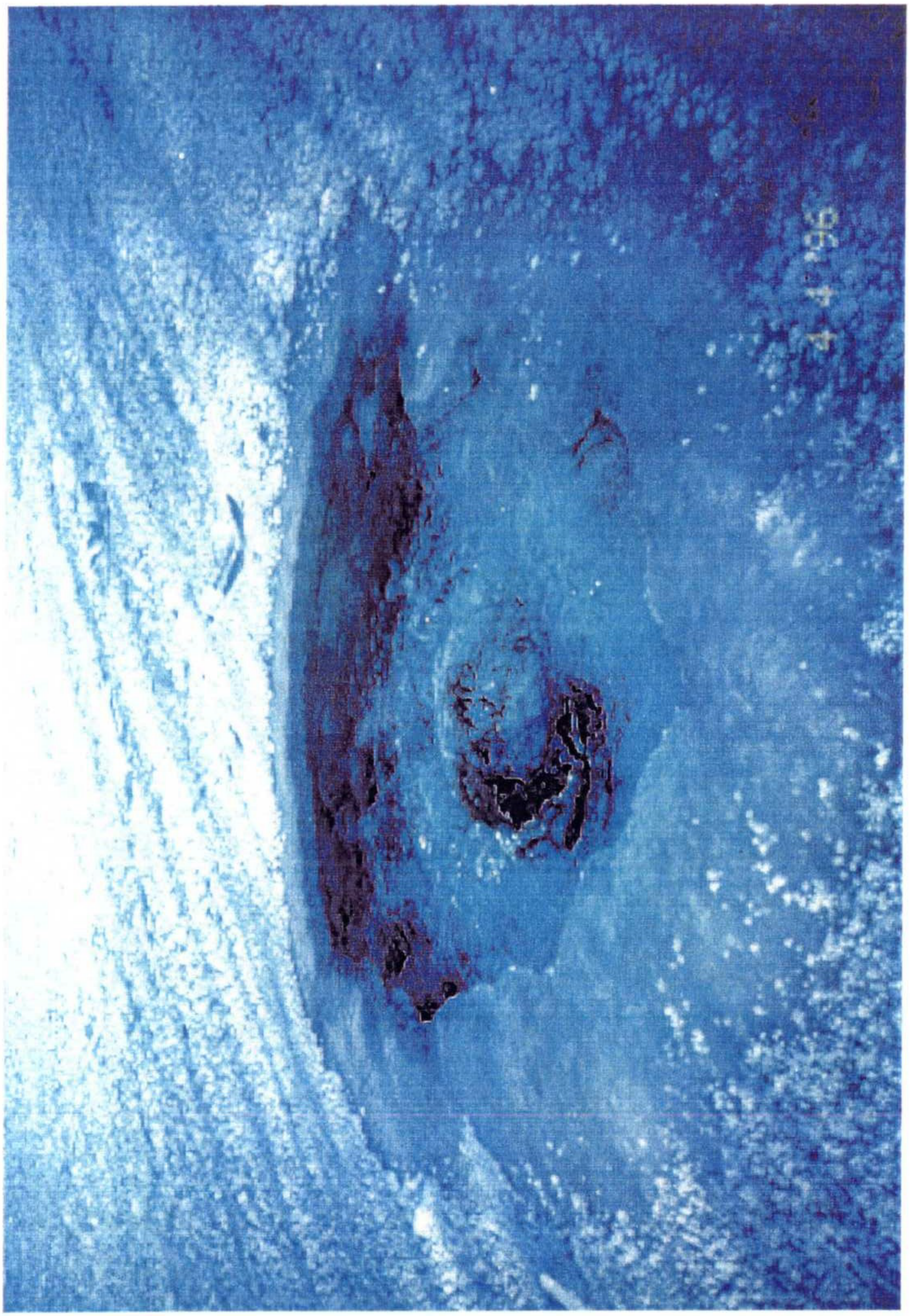

Upstream Limit
of 1995 Fall Survey
N
Small Groundwater
Discharge Area
Auger Hole
Downstream Limit
1995 Fall Survey
(Top of Aufeis Field)
100 m
Aufeis Field
4 6 '96

Figure 9. The hole and upwelling water on Fish Creek (S. Sandstrom).


4 4 '96

APPENDIX 1. Budget for Spring Reconnaissance, 1996[a]

	TOTAL FUNDS	GRRB FUNDS	DFO FUNDS
1. Travel	952.00	952.00	
2. Salary	5080.00	3280.00	1800.00
3. Field Equipment	1795.00	1551.00	244.00
4. Maintenance	1099.00		1099.00
5. Report production	385.00	385.00	
TOTALS	**9311.00**	**6168.00**	**3143.00**
TOTAL BUDGETED and APPROVED	**10500.00**	**6700.00**	**3800.00**
VARIANCE	**+1189.00**	**+532.00***	**+657.00**

* has been carried over into 1996/97 to produce a poster.
[a] amounts are rounded off to the nearest dollar.