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Field Equipment and Procedures for Water Quality Measurements Under Ice

YUKON RIVER BASIN STUDY

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Water Quality Report No. 4

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RESUME

Cette étude de l'oxygène dissous présent sous la surface de glace hivernale a été faite dans le cadre de recherches sur le bassin de la rivière Yukon en 1982-83. Whitfield et McNaughton (1983) ont examiné les dépressions de la concentration d'oxygène dissous présent sous la surface de glace hivernale, ainsi que les facteurs qui les influencent. Aux fins de l'étude, des échantillons d'eau ont été recueillis à tous les mois, d'août 1982 à mai 1983, à des stations situées sur les rivières Takhini et Nordenskiold, deux tributaires de la rivière Yukon. Comme le travail sur le terrain devait être fait pendant l'hiver, à des températures aussi basses que -60°C (Service d l'environnement atmosphérique, 1982), des précautions spéciales ont été nécessaires pour assurer le bon fonctionnement de l'équipement. L'échantillonnage de l'eau se fait de façon quelque peu différente qu'en été. Des instruments spéciaux étaient nécessaires pour percer la glace, et l'équipement scientifique devait être protégé du froid. Ce rapport a pour objet de présenter l'équipement spécial utilisé pour le programme de surveillance continue et pour la cueillette d'échantillons d'eau sous la glace.

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

PLATES

INTRODUCTION

A study of dissolved oxygen under winter ice cover was part of the extensive work conducted on the Yukon River basin in 1982-83. Whitfield and McNaughton (1984) examined the occurrence of dissolved oxygen (DO) depressions under winter ice and investigated the processes involved. To meet objectives of that study, water samples were collected each month from August 1982 to May 1983 at stations located on the Takhini and Nordenskiold Rivers. Since the field work was scheduled during the winter season when temperatures as low as -60°C have been recorded, (Atmospheric Environment Service, 1982) special preparations were needed to ensure proper functioning of the equipment. The sampling of water in winter conditions requires a different approach than does summer sampling. Additional equipment was required to drill or cut through the ice and to protect scientific equipment from sub-zero degree temperatures. This report describes the special equipment and sampling methods required for the continuous monitoring program and for the under ice collection of water samples.

METHODS

I. CONTINUOUS MONITORING

Field Equipment

A Hydrolab system 8000 was used for continuous monitoring of temperature, dissolved oxygen, conductivity, pH, redox potential and depth. A detailed account of the operation of the Hydrolab system for water quality data collection is provided by Whitfield (1984). Prior evaluation of Hydrolab instruments by the Water Quality Branch (Atlantic Region), indicated a problem in cold weather (-20°C air temperature) with ice forming over the electrodes. Consequently a protective insulated box was needed to ensure continuous operation of the instruments (Plate 1, Figure 1).

This insulated box was designed to incorporate the following:

1. A heat source to maintain a temperature of +10° to 20°C.
2. Insulating material for heat retention.
3. Accessibility to the instruments and visual observations.
4. Attachments for moving the box in the field.
5. Precautionary measures to protect against vandalism.

To maintain a constant temperature within the box, a thermostatically-controlled propane heater was selected. This unit had a specified

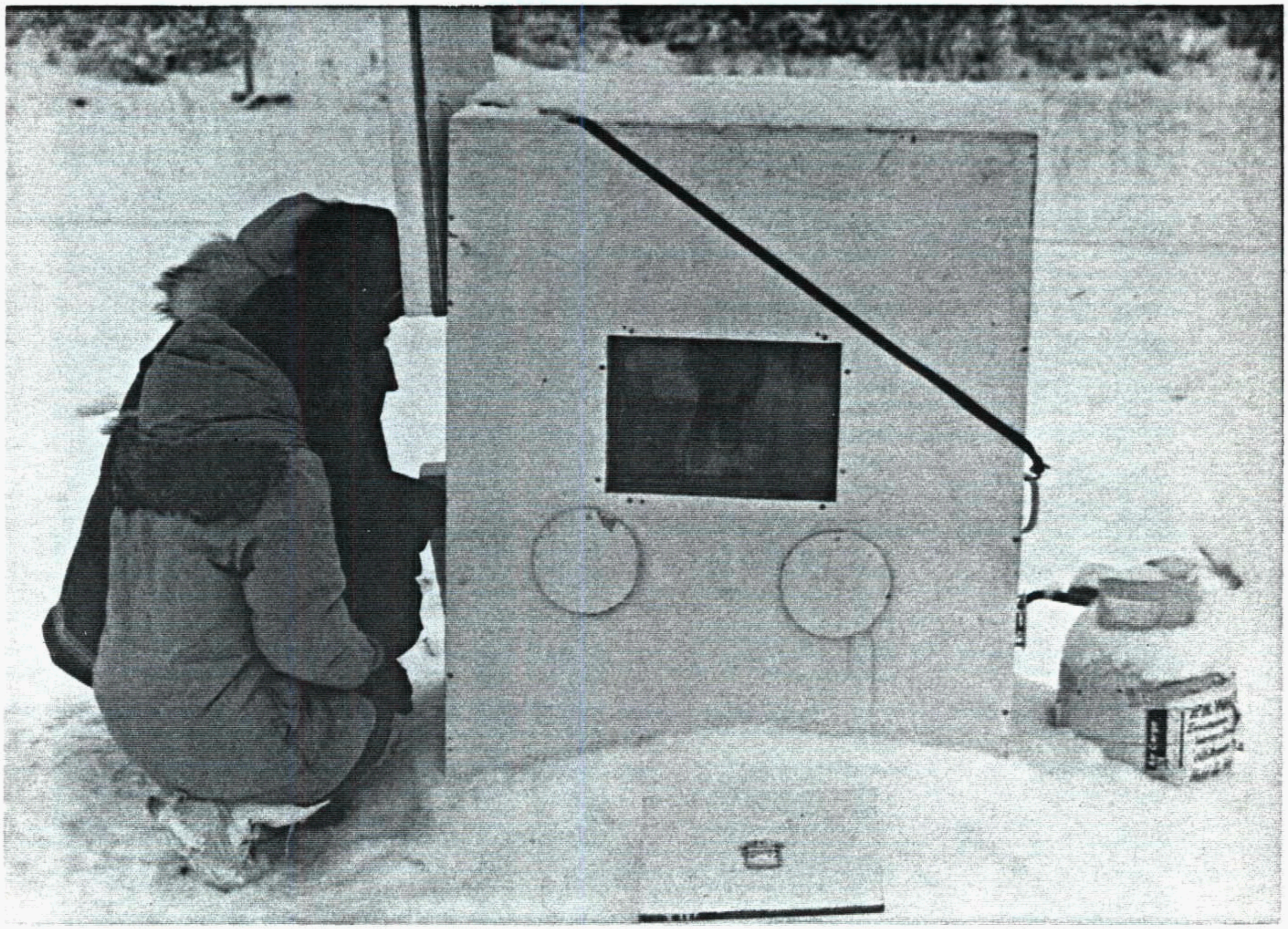

Plate 1 Insulated field box constructed for the Hydrolab 8000.

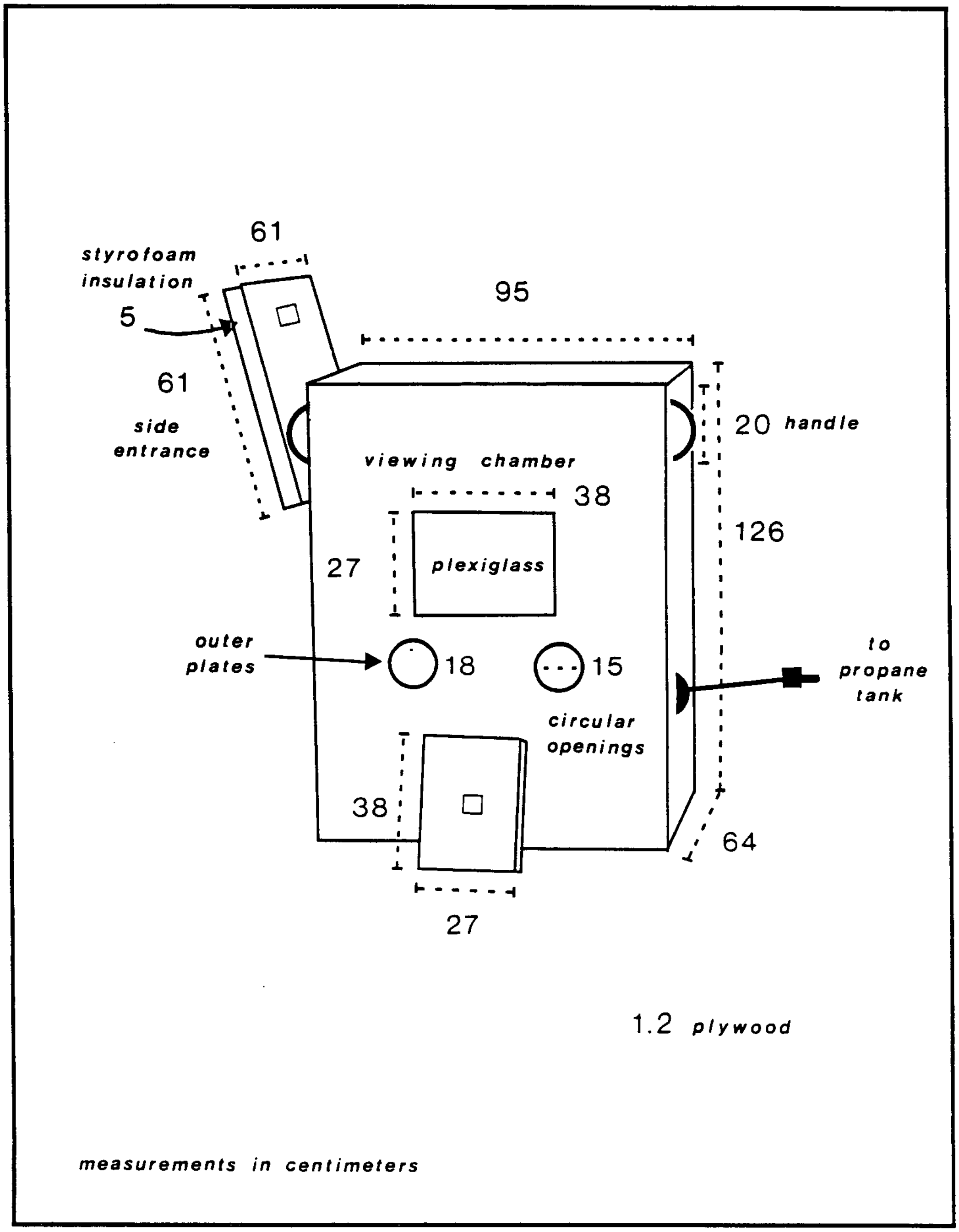

Figure 1 Specifications of the insulated field box for continuous monitoring.

fuel consumption of 0.056 kg per hr. The safety features included electronic ignition and automatic safety shut-off systems. Additional equipment required to operate the heater were a propane tank, regulator and 12 volt battery to operate the venting and safety shut-off systems. Specifications of the heater along with the continuous monitoring equipment are listed in Table 1.

Panels of styrofoam insulation were attached to the inside of the box. This type of insulating material was selected for its low thermal conductance, light weight and availability. Styrofoam SM (extruded polystyrene) was used for the outer layer of insulation (5 cm width, R value = 10) and styrospan (expanded polystyrene), a little less costly, for the inner layer (5 cm width, R value = 7).

The box had a side door to provide adequate access to the instruments. During severe weather conditions or when a visual readout was needed, access could be gained from two circular openings on the front. This access was covered by two swinging outer plates and insulated with removable styrofoam. A window constructed with double panes of plexiglass was located above the access holes.

The box was designed so that the height would allow the data transmitter and accessories to be stored vertically. This also allowed the transmitter to be lowered through the bottom opening to the sampling hole. The box width accommodates the heater and

TABLE 1 Specifications for Field Equipment in Continuous Water Quality Monitoring

Equipment	Manufacture	Model No.	Dimensions	Weight	Power/Fuel
Heater	B.D. Wait Co.	3P12	35.5 x 30.5 x 12 cm	4.0 kg	12 v DC/propane
Battery 12 volt	Yuasa	YB14L-A2	21 x 14 x 10 cm	4.5 kg	charger pack (12 hours)
Data Control Unit	Hydrolab Corporation	8002-031	30.5 x 20.3 x 21.6 cm	3.2 kg	12 v DC
Data Transmitter with Carrier/Circulator	Hydrolab Corporation	8100-161 8400-D10	diameter 9.5 cm length 91 cm	3.7 kg	12 v DC
Data Cable	Hydrolab Corporation	8300-005 8300-050	5 m 50 m		
Battery 12 volt	Globe Battery Division	PP 12120 gel/cell	22.2 x 8.3 cm	5.9 kg	charger pack (20-36 hours)
*Propane Tank and Regulator	Coastal Propane	Y200		9.0 kg	propane

* Located outside insulated box

insulation. The volume of the box was enough to contain all equipment including the propane tank during extreme weather conditions. Another factor taken into consideration in determining the size was the capacity of the heater and the possible damage to the instruments from direct heat.

The box was equipped with handles and to reduce the possibility of vandalism it was painted white for low contrast against the snow. The purpose of the equipment was identified on the outside of the box and side entrance locked.

Sampling Methods

Prior to each field trip the Hydrolab system was calibrated, batteries charged, and the propane tank filled. At the sampling station the surface snow was removed and a hole drilled through the ice with a power auger (Plate 2). The auger used was a Model 4309 Stihl gear box ice drill with Model 08S Stihl power head. When the ice thickness exceeded 1.5 m an extension was attached to the drill. The bottom opening of the insulated box was positioned over the sampling hole and surface snow packed around the box. The propane tank and battery were then connected to the heater. After the heater began operating, the Hydrolab equipment was installed and connected. A 3.6 kg weight was attached to the bottom of the transmitter carrier and lowered down the sampling hole to a depth approximately one metre

Plate 2 Drilling through river ice.

below the undersurface of the ice. A series of measurements for each variable were manually displayed and recorded every minute until the readings stabilized to ensure the equipment was functioning (Plate 3). The data control unit was set on automatic and measurements were logged every 15 minutes. To ensure the unit was logging, data were recorded from the digital display observed through the viewing chamber for three intervals (45 minutes). Daily checks were completed on the equipment and the battery for the heater was changed on alternate days.

Comments

The only problem experienced with the heating system was with the built-in safety system. The system has an automatic shut-off in case of a blocked vent, gas or electrical interruption, incomplete combustion or low battery. When the outside temperature started to drop below -15°C the battery would last approximately 48 hours. Although the heater put only a slight drain (less than 1/3 amp) on the battery, it does require full voltage (12 volts) at all times. If the voltage drops below a minimum (10 volts) the heater will automatically shut off. When this happens the temperature inside the box would eventually decrease, affecting the batteries needed to maintain data storage in the data control unit. The battery for the heater was changed every 48 hours to avoid this problem.

Plate 3 The Hydrolab 8000 shown inside insulated field box.

Another problem was associated with the recovery of the logged data from the memory unit. When the data storage capacity was full, the unit would have to be transported to Whitehorse. Only after the memory was empty could the unit start logging data again. To be able to transfer the data to Vancouver our field schedule had to coincide with the use of a terminal. On several days when the unit could have been logging data, time was spent waiting to recover previous measurements.

II. WATER QUALITY SAMPLES

Field Equipment

When the river was covered with ice, water samples were obtained with a portable sampling pump operated inside an insulated field box (Plate 4, Figure 2). The box was insulated with styrospan (expanded polystyrene) for the inner layer and styrofoam SM (extruded polystyrene) on the outer layer giving a thickness of 10 cm of insulation on all sides. Two openings covered by two outer plates were located on the front panel. The top of the box had a double pane plexiglass window. The chamber and side access allowed easy pump operation for the collection of samples (Plate 5). The top of the box opened for access to the equipment, and to exchange water sample bottles. The lid remained open during transit allowing the heat in the truck to enter. The bottom opening of the box was approximately 14 cm in diameter. The sampling line was inserted through this opening to the sampling hole. A portable Masterflex sampling pump (Horizon Ecology Co., Model 7520-10) was used to collect the samples. The size of the unit was 34.5 x 23 x 22.5 cm (Plate 6). Silicone tubing in the pumphead was attached to a tygon tubing line. The pump could operate with internal batteries for approximately 2.5 hours. The batteries could be recharged with either a 12 volt DC or AC source. An external 12 volt battery or a cable with an adaptor for fitting into a vehicle cigarette lighter was used for extended field use.

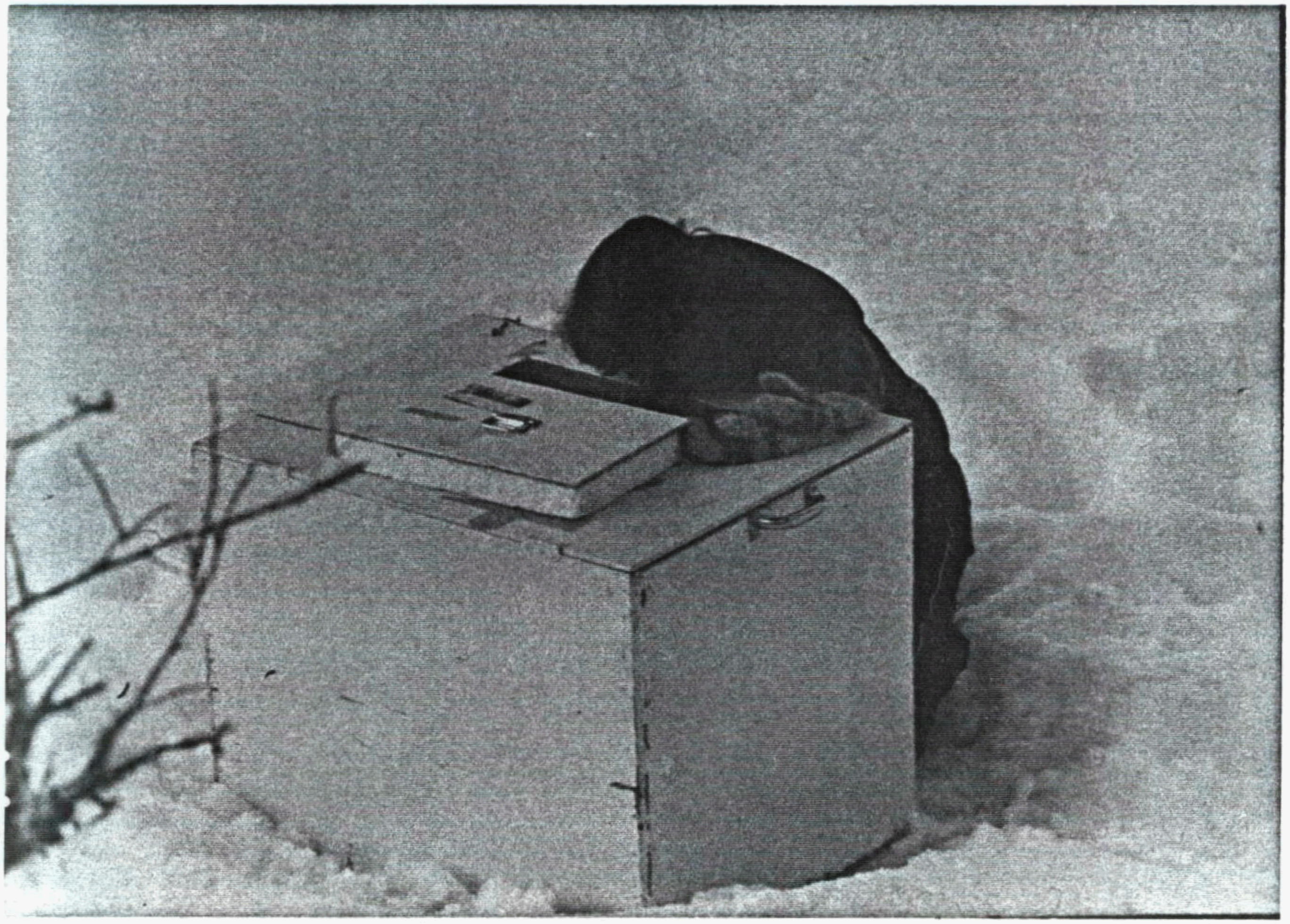

Plate 4 Insulated field box for collecting water quality samples.

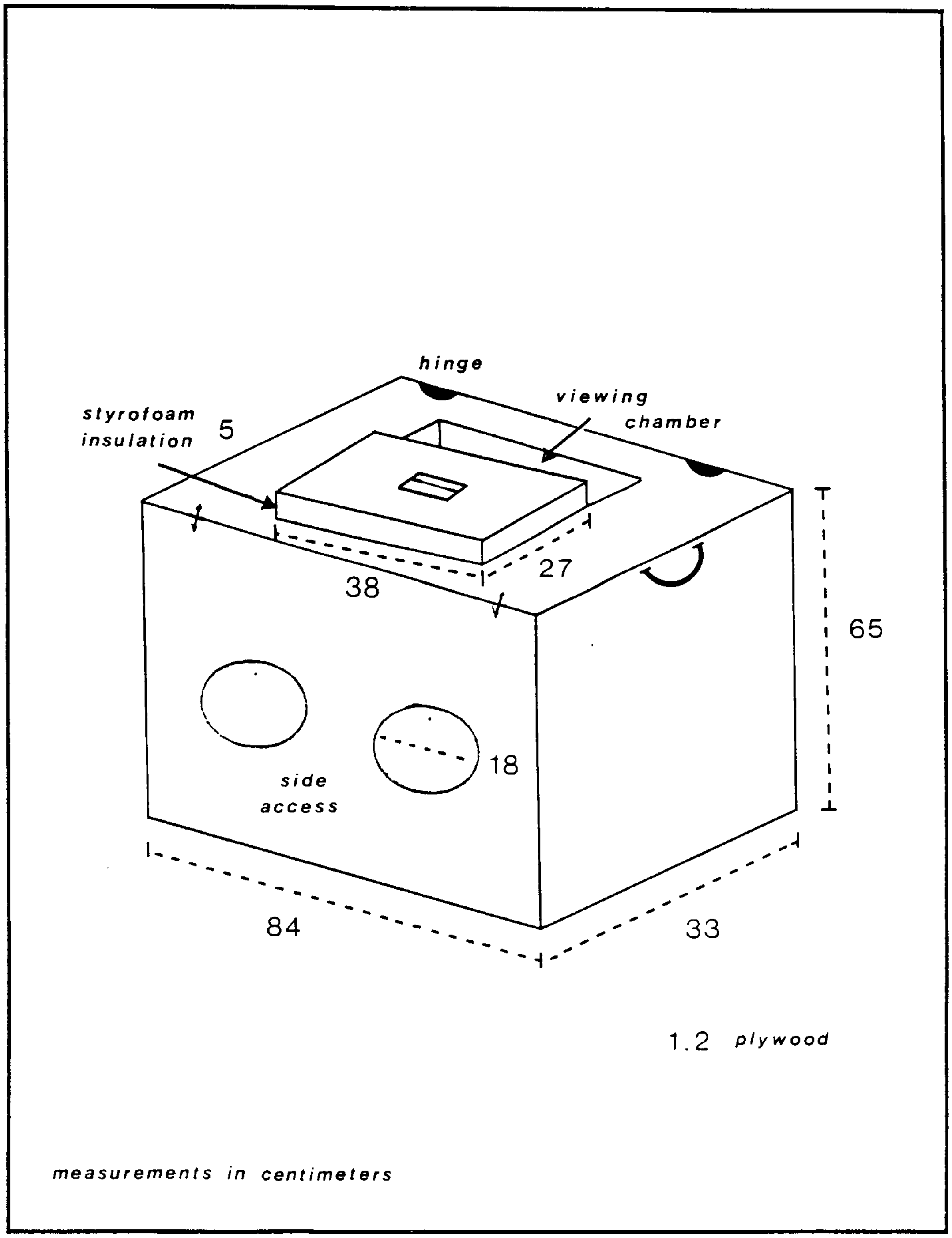

Figure 2 Specifications of the insulated field box for collecting water quality samples.

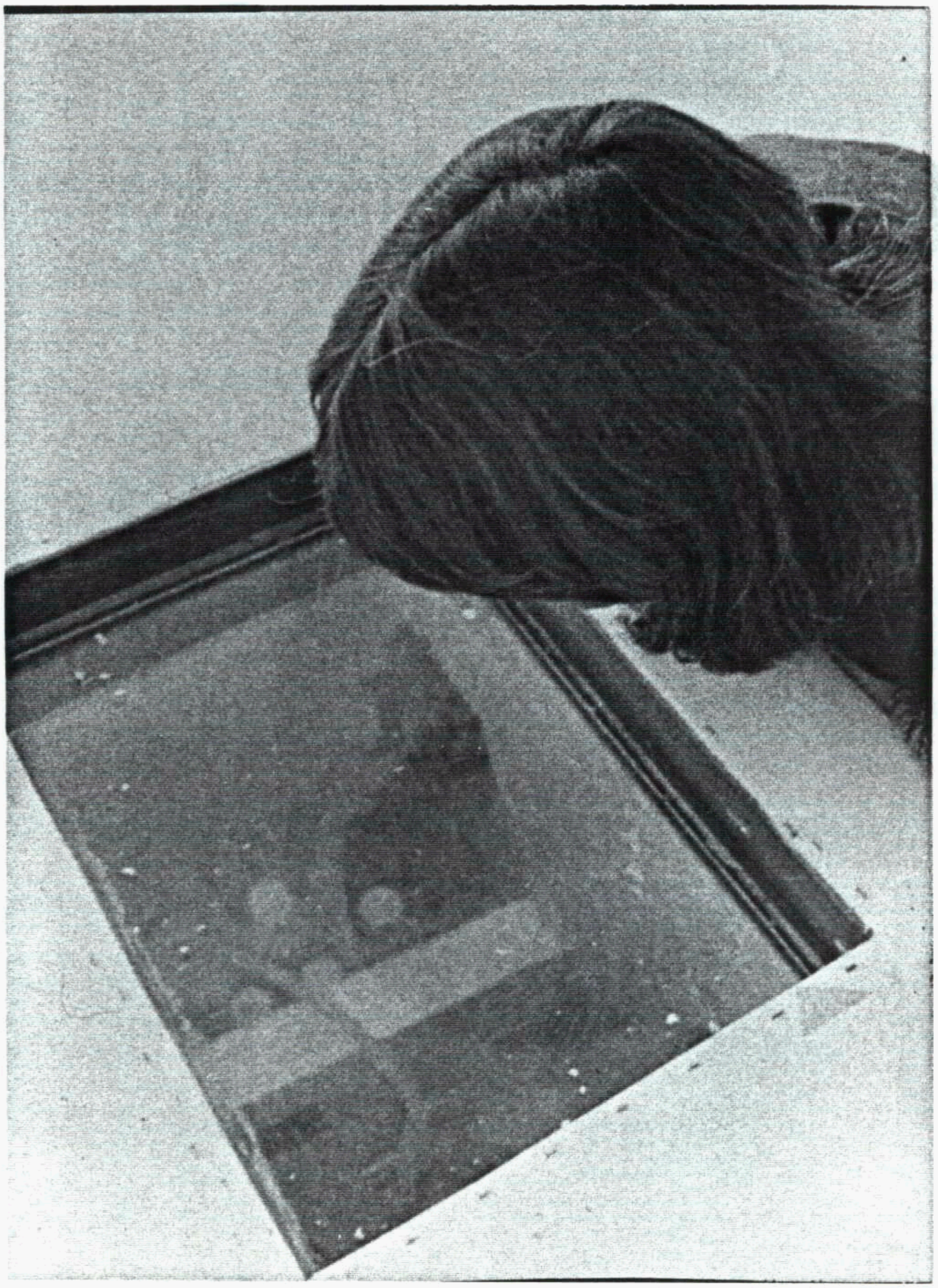

Plate 5 Water samples being collected using the sampling pump.

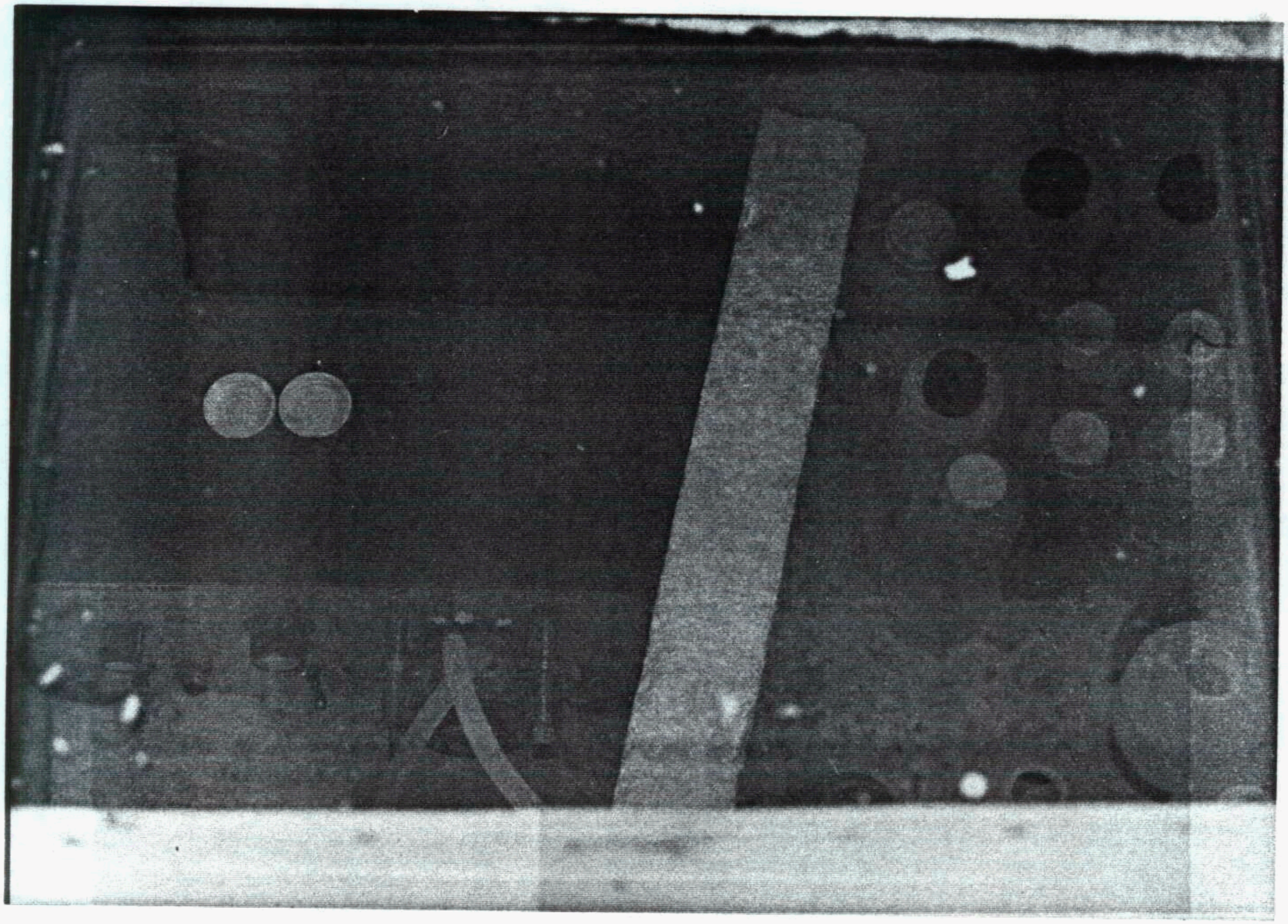

Plate 6 Field equipment inside insulated box for collecting water samples.

Sampling Methods

In early winter and spring sampling holes were drilled only once at each site. On the next sampling day the surface ice was removed with either an ice chisel or axe. In late November, with sub-zero degree temperatures, sampling holes had to be drilled daily. Floating slush ice which accumulated in the hole after drilling, was removed and the water was allowed to flow freely for one to two minutes to avoid possible contamination of the samples. A sampling line attached to a 240 gm weight was placed through the bottom opening in the insulated box and down the hole. The opening of the box was positioned on top of the sampling hole to prevent the line from freezing. Samples were pumped from underneath the ice to the appropriate sample bottle inside the box. Preservation of the dissolved oxygen samples was completed immediately after sampling using the azide modification of the iodometric (Winkler) method. This procedure involved adding specific amounts of manganese sulfate and alkali-iodide-azide solution to the samples (APHA, 1975). These reagents were stored in teflon bottles inside a wooden box. Automatic pipettes were used to add the solutions to the sample bottles. After the samples were preserved each was placed into a box which was placed inside a shipping container for additional protection of the glass bottles.

Field Measurements

Field measurements were determined for temperature (air and water), pH, and conductivity during the sample collection. The water depth and ice thickness at the site were also recorded. Field-measured variables were analysed using the following equipment:

VARIABLE	EQUIPMENT
temperature (°C)	Ertco Pocket Thermometer
pH (units)	Metrohm pH Meter (Model E488)
conductivity (µs/cm)	Beckman Conductivity Meter (Model RB3-338)
water depth (cm)	(estimated from tygon tubing)
ice thickness (cm)	(estimated from ice auger depth)

Instruments and appropriate buffer solutions were thoroughly checked before the field program started. The field equipment were then stored in shipping containers (Techstar Plastics, Model 0402A, 61 x 51 x 31 cm) protected on all sides by styrofoam. The containers was transported by air to Whitehorse where meters were checked and recalibrated. The meters remained in the container during transport to the sampling location and during sampling. This provided protection from truck movement and extreme temperatures.

One sample was collected at each site in a 500 ml polyethylene bottle. This sample was taken to the truck, shaken and decanted into two wide mouth polypropylene bottles. The thermometer was rinsed with a small quantity of the sample after which it was immersed into the first sample and temperature recorded. The pH meter was calibrated with specific buffer solutions. The electrode was rinsed with a small portion of the sample, put into the sample bottle, allowed to stabilize, and a reading was taken. The sample water was then discarded. The conductivity meter was calibrated using two KCl solutions. The probe for the meter was rinsed with a small amount of water from the second sample bottle and then inserted into the sample. The conductance was recorded after the readings stablized. The water depth and ice thickness were easily estimated by the known length of the field equipment being used.

Dissolved Oxygen Analysis

The dissolved oxygen samples were taken to the EPS laboratory in Whitehorse for analysis. Determination of the dissolved oxygen content was completed through titrimetric procedures outlined in the APHA (1975). A portable field box (Plate 7) contained all the equipment required for titration. Box dimensions were 83.8 x 64.8 x 33.0 cm and constructed from 2.0 cm plywood. The reagents for the preservation of samples and titrant were prepared in

Vancouver and shipped to Whitehorse before each field trip. The sodium thiosulphate solution was standardized before titrating the DO samples. This procedure was completed after the final reagent H_2SO_4 was added to the samples. An automatic pipette (Scientific Glass Apparatus Company, No. JP-6000) was used to remove 100 ml of sample from each bottle. A vacuum system was created using a large bottle and rubber bulb aspirator drawing the sample into the pipette. The sample was transferred into a 250 ml Erlenmeyer flask and put on top of the magnetic stirrer situated under a 10 ml burette. Another vacuum system was used to fill the burette with exactly 10 ml of titrant. While the sample in the Erlenmeyer flask was being titrated, 100 ml of solution from another bottle could be transferred with the automatic pipette. This arrangement enabled two samples to be titrated in approximately five minutes.

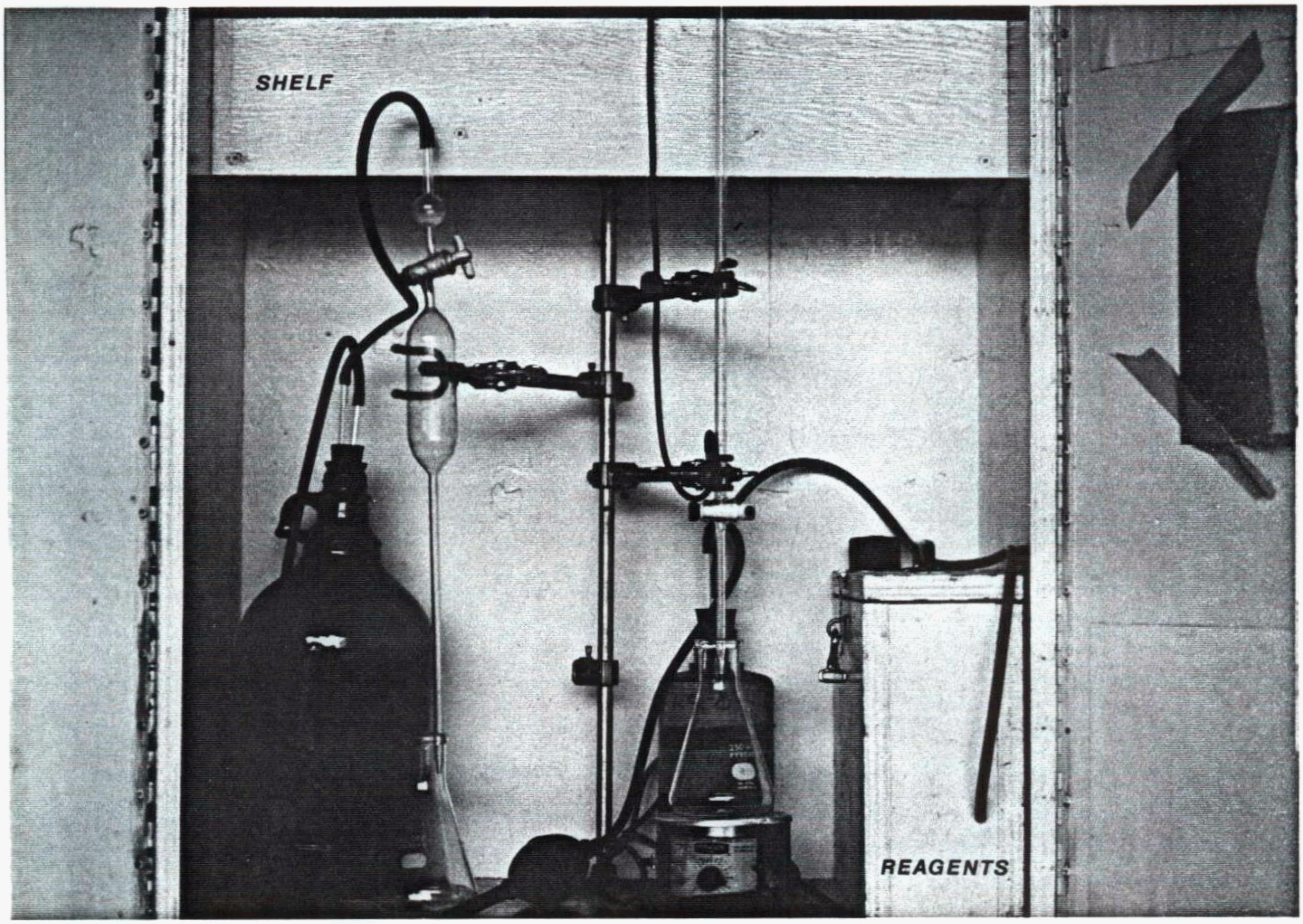

Plate 7 Portable field box and equipment for dissolved oxygen determination

RECOMMENDATIONS

Both the insulated boxes described are considered prototypes, designed to ensure continuous operation of the monitoring equipment and to prevent samples from freezing in sub-zero degree weather. During the field program both boxes were satisfactory but some modifications would improve the operation of these. To improve on the initial design the following is suggested.

CONTINUOUS MONITORING

1. The size and weight of the monitoring box should be reduced for more portability in the field. The height and width are restricted as discussed earlier by the transmitter and heater, however the length of the box could be altered. This measurement would depend on the amount of space required for the monitoring equipment. More vertical space could be utilized by inserting shelves to reduce length. A reduction in the weight could be made by using 0.6 cm instead of the 1.2 cm plywood.
   Also, in designing an insulated box the size restrictions of shipping by air and field vehicle must be considered.

2. The bottom opening of the heated box would be best left open when over the sampling hole. This should allow the heat from the box to keep the sampling hole from freezing over. A circular piece of styrofoam, at the onset of the program, was inserted into the opening to retain the heat during monitoring. Within a day the surface water in the sampling hole was frozen. Retrieval of the transmitter would have been difficult if left for several days.

3. A separate insulated box over the propane tank or even storing it inside the box with the heater may be advised if expected outside temperatures are lower than -30°C.

4. If the sampling site is a considerable distance from the access road, special attachments to the box would be needed to make transportation easier. Converting old cross-country/downhill skis, toboggan, or using a snowmobile with a trailer or sled would be useful.

5. A microcomputer would be useful for recovery of logged data in the field. This instrumentation would allow data retrieval from the monitoring equipment at the sampling site. For our system, an Osborne 1 microcomputer was purchased capable of storing the data on diskette. Equipped with a modular-demodular (modem) device, the Osborne could later transmit the data to our files

stored on the mainframe computer at Simon Fraser University (SFU). Whitfield (1983) details the interfaces needed to make the data transfers from the Hydrolab to the Osborne to SFU.

6. Another type of battery or heater may be warranted depending on the sampling interval and remoteness of location. The sampling frequency of the dissolved oxygen study enabled us to check the monitoring system and replace the battery for the heating unit. The effective usable life of the battery was 48 hours. A more powerful battery or a different type of heater would be necessary if the required interval is longer than 48 hours.

WATER QUALITY SAMPLING

In designing an insulated box for water quality sampling the main concerns are the weight and size. For improvement some suggestions are:

1. The box should be constructed from 0.6 cm plywood instead of 1.2 cm. Corner brackets or braces may be advisable to strengthen the box if 0.6 cm plywood is used.

2. The size of the box could be reduced. The height should remain the same for easy access and handling of the bottles but the length or width could be decreased. The length and width depend

on the amount of insulation, sampling pump measurements and the number of sample bottles required at each site. At several of our sampling sites banks were eroded and river depth low. To return the box to the truck would sometimes require lifting it one to two metres and result in tipped bottles. To prevent the bottles from spilling over, the side of the shelves should have wooden dowels or elastic cord.

3. Additional considerations include the diameter of the bottom opening used to obtain water samples. The opening need be only 10-12cm, any larger and the bottles may fall out during sampling or transporting. In addition there could be unnecessary heat loss through the opening or the sampling line could be exposed, causing the water inside to freeze instantly. To prevent this situation, the tubing or line could either be wound around the handle or suspended on a hook or other device. If the water in the tube did freeze, it could be thawed in the insulated box by the warmth of bare hands. The tube should be completely thawed before any samples are taken, especially for dissolved oxygen. Frazil ice in the tygon sampling line would cause an interrupted flow which entrained air bubbles into the sample.

4. At each site 23 samples were collected, approximately eight litres of water. The time required to collect the samples using the pump was 20-25 minutes. The heat inside the box dissipated

with each bottle of water collected causing condensation on the plexiglass. This in turn made it difficult to view and fill the bottles. To reduce the amount of condensation the box was placed near the truck's heater between sampling sites. When we reached the next sampling site the necessary sample bottles would be put into the box and the lid would be closed to retain the heat as long as possible. Just in case, the dissolved oxygen bottles were the first to be filled in order to observe if any air bubbles were contaminating the sample.

5. Waterproof gear is recommended to prevent getting clothes wet while kneeling in snow and ice to obtain samples.

6. For winter sampling adequate safety gear is essential. A list of equipment is provided in Appendix 1. This list was comprised partially from our inventory and that specified in "Northern Survival" Department of Indian and Northern Affairs (1979) and "Down but not out" by the Royal Canadian Air Force (1970). Each list will differ depending on the sampling location, climatological conditions and transportation. Field personnel involved in winter field work should be provided with winter survival training.

ACKNOWLEDGEMENTS

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LITERATURE CITED

American Public Health Association, 1975. Standard Methods for the Examination of Water and Wastewater. 14th Edition.

Atmospheric Environment Service, 1982. Annual Meteorological Summary, 1980-1982. Whitehorse, Yukon Territory. Environment Canada.

Department of Indian and Northern Affairs, 1979. Northern Survival. Department of Supply and Services. Ottawa, Ontario.

Environment Canada, 1979. Analytical Methods Manual. Department of the Environment. Inland Waters Directorate. Water Quality Branch. Ottawa, Ontario.

Royal Canadian Air Force, 1970. Down But Not Out. A Practical Guide to Survival in All Climates. RCAF Survival Training Staff. Department of Supply and Services, Ottawa.

Whitfield, P.H., 1983. Interfacing the Osborne 1 to the Hydrolab 8000 and to Simon Fraser University's MTS Service. Osborne Support Document #1. Inland Waters Directorate. Environment Canada. Vancouver, B.C.

Whitfield, P.H., 1984. Operation of the Hydrolab 8000 System for Collection of Water Quality Data. Yukon River Basin Study. Water Quality Working Group Report No. 5. Inland Waters Directorate. Environment Canada, Vancouver, B.C.

Whitfield, P.H. and B. McNaughton, 1984. Comparison of Dissolved Oxygen Processes Under Ice in Two Southern Yukon Rivers. Yukon River Basin Study. Water Quality Working Group Report No. 3. Inland Waters Directorate. Environment Canada, Vancouver, B.C.

APPENDIX 1

Winter Safety Equipment

Personal Gear	Travelling Gear	Survival Gear
Arctic Parka, Downfilled Vest, Waterproof Snow Boots, Hiking Boots, Chest Waders (plus repair kit), *Hat/Gloves/Scarf, *Wool pants/Sweater, *Socks/Undergarments, Waterproof "Warmups", Life Jacket, Sunglasses, Camera.	Flares, Spare Tire, Chains, Spare Plugs (plus other assorted parts), Wheel jack, Extra fuel, and Oil, Antifreeze for gasoline and radiator, Flashlight, First Aid Kit, Tool Box, Axe/shovel/ Ice Chisel, Winch, Heavy Rope, Extra Keys	Tent, Sleeping Bag, Thermal (space) Blanket, Candles, Flares, Waterproof Matches, Signalling Mirror, Flashlight, Snare Wire, Nylon Shroud Cord, Topographical Map, Compass, Snow Saw Knife, Hooks, Line. First Aid Kit, - razor blade, curved needle, tape, aspirin, small and medium compress bandage, bandaids. Gas Camp Stove, Cooking Fuel (solid), Cooking Container, Spoon, Freeze Dried Food, Coffee, Soup Cubes, Tea, Salt, Chocolate. Soap, Orange Garbage Bags, Aluminum Foil.

* Bring extra