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A TEST OF GROUND PROBING RADAR FOR EVALUATING SUBSURFACE CONDITIONS IN PERMAFROST TERRAIN

TUKTOYAKTUK COASTLANDS AREA, N.W.T.

Prepared for

INDIAN AND NORTHERN AFFAIRS CANADA

Prepared by

FRANK THOMPSON

November, 1994

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INTRODUCTION

In the Western Arctic, granular deposits for road building and other construction needs are scarce and generally small. Much of the granular material required is derived from glacial and post-glacial sand and gravel deposits. Buried ice, present in most of these deposits, further limits recoverable reserves and poses logistical and environmental problems unique to permafrost terrain.

The volumes of granular material extracted prior to 1970 were small, but during the 1970's and 1980's there was a substantial increase in demand by the oil and gas industry and local communities. In response to this demand several studies of potential granular sources were undertaken and several deposits subsequently exploited.

Unexpected problems associated with these extraction activities resulted in inefficient use of the granular resources, wasted effort and unnecessary environmental damage. Some deposits selected for development proved uneconomic because of thick overburden cover or unsuitable granular material. Melting of buried ice which was exposed during extraction activities in some of the borrow pits, resulted in surface disturbances and flooding of the pit which limited access to the remaining granular material. Large volumes of water issuing from some of these ice rich pits posed potential environmental concerns. Many of the abandoned borrow pits are now visually unattractive because they lack vegetation, have steep unstable slopes not in keeping with the natural landscape and are marked by irregular water filled depressions.

The problems associated with exploitation of these deposits demonstrates the need for more detailed pre-development subsurface exploration of glacial and post-glacial sources of granular material in the Western Arctic than for deposits where geological conditions are more consistent or where the ground is not permanently frozen.

The Geological Survey of Canada has conducted field tests to determine the effectiveness of Ground Probing Radar (GPR) in defining the extent of buried ice and granular material in permafrost terrain. The borrow pit operator in the Tuktoyaktuk area, Grubens Transport, has also been experimenting with the effectiveness of Ground Probing Radar. The Geological Survey of Canada GPR system employs a separated transmitter and receiver. It provides; a variable antenna frequency so that the most suitable frequency can be selected for subsurface conditions, stackable pulse that yields improved signal to noise ratio and a digital record. It has proved to be effective where ground truth is available but it is time consuming and expensive to operate. Typically up to 2 km. of survey line can be done in one day of operation. The GPR system used by Grubens Transport has the transmitter and receiver mounted together and this unit is towed across the study area to provide a continuous profile record along the survey line. It is commonly used to measure sea ice thickness and is significantly faster and less expensive to operate than the system used the Geological Survey of Canada but its effectiveness has not been proven and it does provide a stackable pulse, variable antenna frequency or a digital record for computer processing. Typically, well in excess of 10 km. of survey line can be done in one day of operation

FIELD PROGRAM

The GPR profiling equipment previously used by Grubens Transport was operating in the Tuktoyaktuk area in April of 1993 to evaluate sea ice type and thickness. This provided a window of opportunity to evaluate the effectiveness of this equipment for defining buried stratigraphy without encountering mob/demob costs. The small granular deposits collectively known as Source 160/161 were chosen for this study because:

- They are easily accessible from Tuktoyaktuk
- Ground truth is provided by exploration drilling (Hardy 1980)
- The Department of Indian and Northern Affairs has conducted studies of these abandoned borrow pits to evaluate their environmental condition and the extent of potential remaining reserves (Thompson 1992)
- The Geological Survey of Canada has conducted GPR studies over some of these deposits
- They comprise both exploited and unexploited granular deposits.
- Thaw ponds have developed in some of the abandoned borrow pits.

The GPR profiling was done by Jim Greer of North-South Consultants, Egremont, Alberta. The recording instruments were mounted inside a Bombardier and the transducer/receiver towed behind on a sled (see photographs in Illustration 1, Appendix A). The profiler was a PR 8300 with a 120 MHz (3020) sea ice transducer. Frank Thompson, consulting geologist of Ottawa, Ontario, selected and laid out the survey lines and provided on-site supervision of the study.

The project was conducted in late winter under cold weather conditions and continuous snow cover. Ten grid lines with a total of 2,600 meters of survey line were laid out in the study areas. Most of the lines were profiled 2 or 3 times to test equipment settings.. The work was completed in approximately 7.5 hours including about one hour traveling time and 0.5 hours for minor repairs to the bombardier.

The window of opportunity to conduct this test survey was too short to permit preparation of a surveyed grid. The survey lines are located relative to topographic features and are considered to be accurate within 35 metres. The first picket on any line is labeled by area, line and control point. Subsequent pickets are labeled by line and control point. Distance between control points along the lines has not been measured and pickets are not evenly spaced. The control points are marked on the profile records and, with the exception of profiles on ponds, all survey pickets were left in the field. The pickets were placed in snow and will now be lying flat. Although any future surveys can be conducted along the same lines there may be some difficulty identifying control points along the lines because the pickets may not all be found during subsequent surveys and some were missed by the bombardier driver during the initial survey.

STUDY AREAS

Source 160/161 A

Four exploration holes were drilled in this area in 1980 (see attached Borehole logs 1 to 4 in Appendix B). This exploration drilling encountered 3.5 to 5.5 metres of sand and gravel interlayered with in excess of 2 metres of erratically distributed ice. A thin cover of organics (less than 0.3 metres) was intersected in most boreholes. The granular material has not been extracted and the original stratigraphy remains intact. Source A is a plateau area and provides easy mobility and a relatively flat surface. For the above reasons this area was considered an ideal testing ground for the profiling equipment. Location of the boreholes and grid survey lines are shown in Illustration 2.

Source 160/161 C

Three exploration holes were drilled on a small hill in this area in 1980 (see attached Borehole logs 17 to 19 in Appendix B). This exploration drilling encountered 2 to 4.5 metres of sand and gravel overlying ice in excess of two metres thick. Granular material was extracted from the hill between 1980 and 1983. Deep water filled depressions formed in the base of the borrow pit due to melt of buried ice exposed by extraction of the granular material. Fresh tension cracks and collapse features, observed on margins of the borrow pit and ponds in the fall of 1991 suggest continued expansion of the ponds.

It has been proposed (Hardy 1986 and EBA 1987) that this borrow pit be recontoured to improve its visual appearance and to recover small volumes of granular material for community use. If additional buried ice underlies this borrow pit, recontouring efforts or removal of granular material could initiate additional thermokarst collapse. In 1991 Dr. A. Judge of the Geological Survey of Canada conducted GPR surveys in the base of the borrow pit and in undisturbed terrain on the east side of the pit. These surveys suggest that buried ice underlies the undisturbed areas but does not underlie the base of the borrow pit. The ponds in the borrow pit were probed in September 1991 and found to be 1.5 to 2.6 metres deep (Thompson 1992). This area was chosen as a part of the present study to:

- Provide a comparison with the GPR survey conducted by A. Judge.
- Determine the location and extent of any buried ice underlying the borrow pit or thermokarst ponds
- Determine if the thermokarst ponds are unfrozen at their base (this condition would enhance melt of any buried ice).

- Determine the location and extent of granular material and buried ice in the unexplored and unexploited highland on the east side of the pit.

Extent of the borrow pit and location of water depth recording sites, data collection sites and grid survey lines are shown in Illustration 3.

Source 160/161 North

No exploration data was available for this area and subsurface conditions are unknown. Granular material was extracted from this area between 1980 and 1985. A deep water filled depression formed on the east side of the pit subsequent to extraction of the granular material. This pond has expanded rapidly since 1985 and fresh tension cracks, collapse features and drowned vegetation observed in the fall of 1991 suggest continued melt of buried ice. This pond was probed in September 1991 and found to be 3.3 metres deep (Thompson 1992).

The thaw pond is approximately 8 metres above Pikiolik Lake and separated from the lake by a ridge less than 20 metres wide.. In 1991 Dr. A. Judge of the Geological Survey of Canada conducted GPR surveys along this ridge. These surveys indicated that a wedge of buried ice probably underlies the southern part of this ridge. This area was chosen for a part of the present study to:

- Provide a comparison with the work conducted by A. Judge.
- Determine if the thermokarst pond is unfrozen at its base.
- Determine the location and extent of any buried ice underlying the thermokarst pond.
- Determine the location and extent of any ice underlying the ridge between the thermokarst pond and Pikiolik Lake.

The margins of the thaw pond were too steep to permit following the survey lines across the pond but the profiling equipment was left running to provide data while the bombardier circled the pond to get a run up the slope [the bombardier requires a large turning radius and is not very maneuverable in rough terrain]. The transducer overturned during this test and readings in some places over the pond are erratic. One survey line [Illustration 4] was run from south to north along the ridge.

DISCUSSION AND INTERPRETATION

The GPR profiles together with annotations by J. Greer, F. Thompson and A. Judge are enclosed with the original of this report. Examples from these profiles are included with all copies. The following discussion is based on the author's review of the GPR profiles and the borehole logs and on consultations with A. Judge and J. Greer. I would particularly like to acknowledge the contribution of Alan Judge in providing his interpretation of the profiles and his suggestions for any future GPR surveys.

General Discussion

The GPR signal is dependent on subsurface conditions. Ice commonly yields a strong reflector (white area) on the profile. Ice wedges show up well because they introduce spatially localized echo trains in the profile. Thick, dry and loose snow can present problems since it exhibits the velocity of the air wave at 0.3 metres/nanosecond and can lead to strong reverberations in the profile from the snow/frozen ground interface. Depth penetration is generally good in sands, gravels and ice but tills or fine sediments such as silt or clay can severely limit penetration. Typically a 100 MHz system can be expected to give between 4 and 20 metres of penetration depending on the materials encountered.

The same vertical distance on the profile records does not necessarily represent the same thickness of materials in the subsurface because velocity of the GPR signal is significantly different in different materials. Velocities range from approximately 0.03 meters /nanosecond in water to 0.15 metres/nanosecond for both ice and frozen granular material. Typical two way travel times are 67 nanoseconds for one metre of water and 13 nanoseconds for one metre of ice or frozen granular material. Horizontal calibration lines on the profiles are printed every 20 nanoseconds (J. Greer pers. comm.) and therefore one calibration line represents approximately 0.3 metres of water and 1.5 metres of ice or frozen granular material.

Profile Records Over Land

The profile records from a purely terrestrial environment (all Lines at Source A and Lines 3 and 4 at Source C) yield surprisingly little variation along the profile or between the different areas (Illustration 5). The irregularities in the first 20 nanoseconds of the record may represent near surface ice wedges and/or ice rich areas in the active layer (Illustration 6). It is suspected that the records from 20 nanoseconds to the bottom of the profiles show largely reverberations (echo) from near surface features and contain little deep-seated geological information. This suspicion is based on the fact that the reflectors repeat each other in character throughout the profile

The origin of the strong reflector (white area) at about 60 nanoseconds on all overland profiles is uncertain. It is very unlikely that it represents a subsurface feature at a depth of 4.5 metres (60 nanoseconds in frozen granular material) and extending over an area of several square kilometres. A geological horizon of consistent depth and thickness is incompatible with the known character of glacial deposits in the Tuktoyaktuk area and there is no indication from the exploration drilling of any continuous stratigraphic horizon at this depth. The snow/ground interface or the ice rich base of the active layer where water is commonly trapped during summer thaw could yield a reflector similar to that observed at 60 nanoseconds. Both the snow/ground interface and the ice rich base of the active layer should be represented in the first 20 nanoseconds of the record but the reflector at 60 nanoseconds could be an echo of near surface conditions. Alternately the reflector at 60 nanoseconds could be a system artifact. Using the airwave velocity of 0.3 metres/nanosecond, a surface feature at a distance of approximately 8 to 9 metres from the receiver would yield a reflector at 60 nanoseconds. In this survey, the bombardier was approximately 7 to 9 metres from the receiver and is considered a possible source for this reflector.

The only profile record from a purely terrestrial environment that appears on preliminary analysis to contain any useful deep-seated geological information is Line 1 at Source North where there is a significant anomaly along the narrow ridge between the thermokarst pond and Pikiolik Lake (Illustration 7). This is consistent with the records obtained by A. Judge using digital GPR in this area which are believed to indicate buried ice. Depth and width of this feature is uncertain but it does suggest that this ridge is, in part, underlain by ice. This has important implications. Melt of buried ice in this area could lead to structural failure of the ridge. In this event, the thermokarst pond could drain rapidly into Pikiolik Lake. A sudden influx of water from the pond of different temperature and chemistry than that in the lake and carrying granular material and silt eroded from the ridge may have a negative impact on aquatic life in Pikiolik Lake.

Profile Records over Ponds

Lateral transition between terrestrial landscapes and the ponds is very distinctive. The records over ponds are much quieter (smoother), possibly indicating a gentler ride for the antennas, and the record from 20 to 80 nanoseconds is not dominated by strong echoes. At both Source C and Source N the GPR records suggest ponds of irregular depth that are, in places, unfrozen at their base (Illustration 8). This has important implications. Where ponds are deep enough that they do not freeze completely during the winter; annual ground temperatures under the pond will remain above freezing year round. As a result buried ice underlying such ponds will melt more quickly and to a greater depth than under shallow ponds that freeze completely. The profile records below the base of the ponds are dominated by echoes and appear to contain no useful geological information.

The origin of the strong reflector at about 50 nanoseconds in the ponds at Source C is uncertain but it's character is suggestive of the ice/water interface. Ice on the ponds is expected to be less than 2 metres thick and should be represented in the first 20 nanoseconds of the record but the reflector at 50 nanoseconds could be an echo of the ice/water interface. As is the case for the overland profiles, it is possible that this is a system artifact and that the bombardier is the source of the reflector. This reflector is far more varied and broken on land based profiles than over ponds. This may result from greater vibrations or movement of the antenna relative to the bombardier over hummocky ground than over an ice surface. The weaker and curvilinear reflector varying between 70 and 100 nanoseconds probably represents the base of the pond. The irregular curvilinear aspect of the records under the ponds is strongly suggestive of thermokarst collapse features. The similar reflectors below this feature are likely echoes of the base of the pond.

Assuming that the base of the ice is hidden in the first 20 nanoseconds of the record, depth of water under the ice varies from 0.8 to 1.2 metres and total thickness of ice and water would be approximately 2.0 to 3.0 metres. This is consistent with the measured depth of water which was 1.5 to 2.6 metres in late September of 1991.

RECOMMENDATIONS

In this test study, the Ground Probing Radar system previously used by Grubens Transport to evaluate granular deposits provided only very limited information on subsurface conditions. The GPR did identify probable buried ice in the ridge west of Pikiolik Lake and indications of near-surface ice wedges throughout the study areas but, the profile records from a purely terrestrial environment generally provided no useful geological information from depths in excess of 2 metres. The profile records from thermokarst ponds provided information on conditions in the pond but no useful geological information on conditions below the base of the pond.

The results from this survey do not necessarily indicate that this system is incapable of evaluating subsurface conditions in areas of permafrost. The disappointing results are quite possibly a reflection of the equipment and equipment setting used for this test survey. Although the antenna used is capable of providing 5 to 20 metres of depth penetration under ideal conditions, it is possible that the test survey would have been more successful if the GPR was equipped with a lower frequency antenna and digital recording equipment.

Further studies to determine the potential of this GPR system are clearly merited. If this system can be adapted to provide useful information on subsurface conditions it has tremendous potential. It is fast and relatively inexpensive. It could be used in conjunction with exploration drilling prior to exploitation of granular deposits to provide more complete information at a lower cost than drilling alone or employed after the pit is abandoned to help guide any restoration efforts. Recommendations to assure that any further studies will fully evaluate the potential of the GPR are summarized below.

- Ground Probing Radar should be equipped with transducers of frequencies ranging from 25 to 120 MHz and start-up tests run where subsurface conditions are well defined to choose the appropriate antenna frequencies.

The transducer used for this survey, a 120 MHz sea ice transducer, was most likely not the most suitable for defining buried sediments. Frequencies of 50 and 25 MHz are more commonly used for profiling through sediments and generally provide deeper penetration whereas higher frequencies are used to map ice wedges.

- Ground Probing Radar should be equipped with modern digital recording equipment.

The GPR used for this survey provided a paper record rather than a permanent electronic record. It is therefore not possible to determine if there is additional subsurface information, embedded in these records but masked by the strong echoes recorded.

- There should be at least one location where subsurface conditions are well defined to provide a comparison with the GPR records.

Although GPR can be very successful at following stratigraphic horizons between boreholes and can detect changes in lithology, it is still developing in terms of providing absolute identification of materials or in providing depth to a stratigraphic horizon without control points or velocity profiles. For this study it was not possible to provide an accurate location of the ground truth relative to the GPR survey lines because the locations of the boreholes from the 1980 exploration program are not recorded on the ground.

- GPR test surveys and interpretation of their results should be supervised by someone fully familiar with Ground Probing Radar.

Application of GPR for evaluation of subsurface stratigraphy is still in the development stages. Each study is unique and should be evaluated independently to determine the most suitable equipment and equipment settings for the subsurface conditions. Similarly, it is not possible yet to apply simple rules to interpretation of GPR records.

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APPENDIX A
ILLUSTRATIONS

Illustration 1. Photographs of bombardier and the transducer under tow.

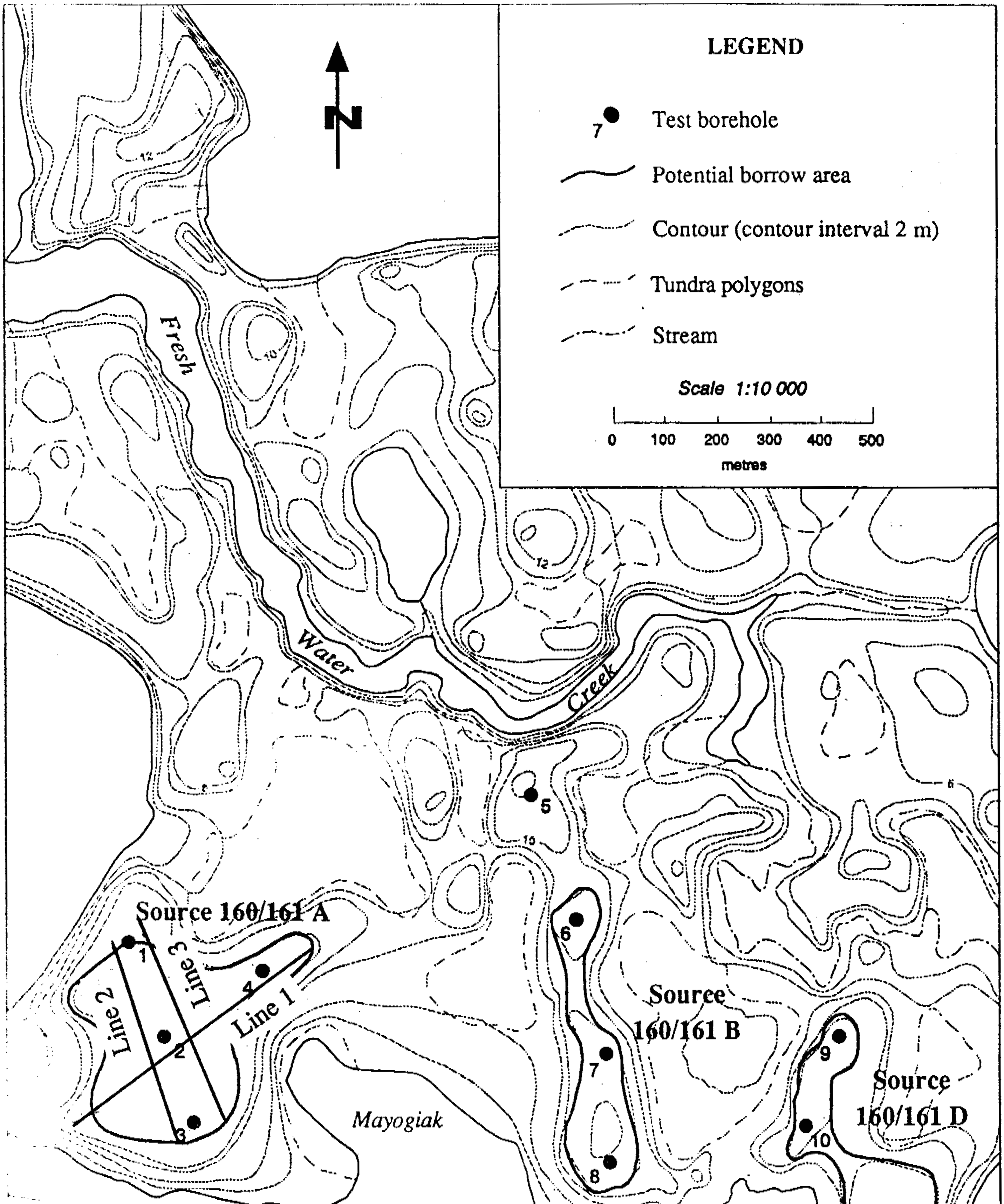


Illustration 2. Location of boreholes and grid survey lines at Source 160/161 A (modified after Hardy 1980).

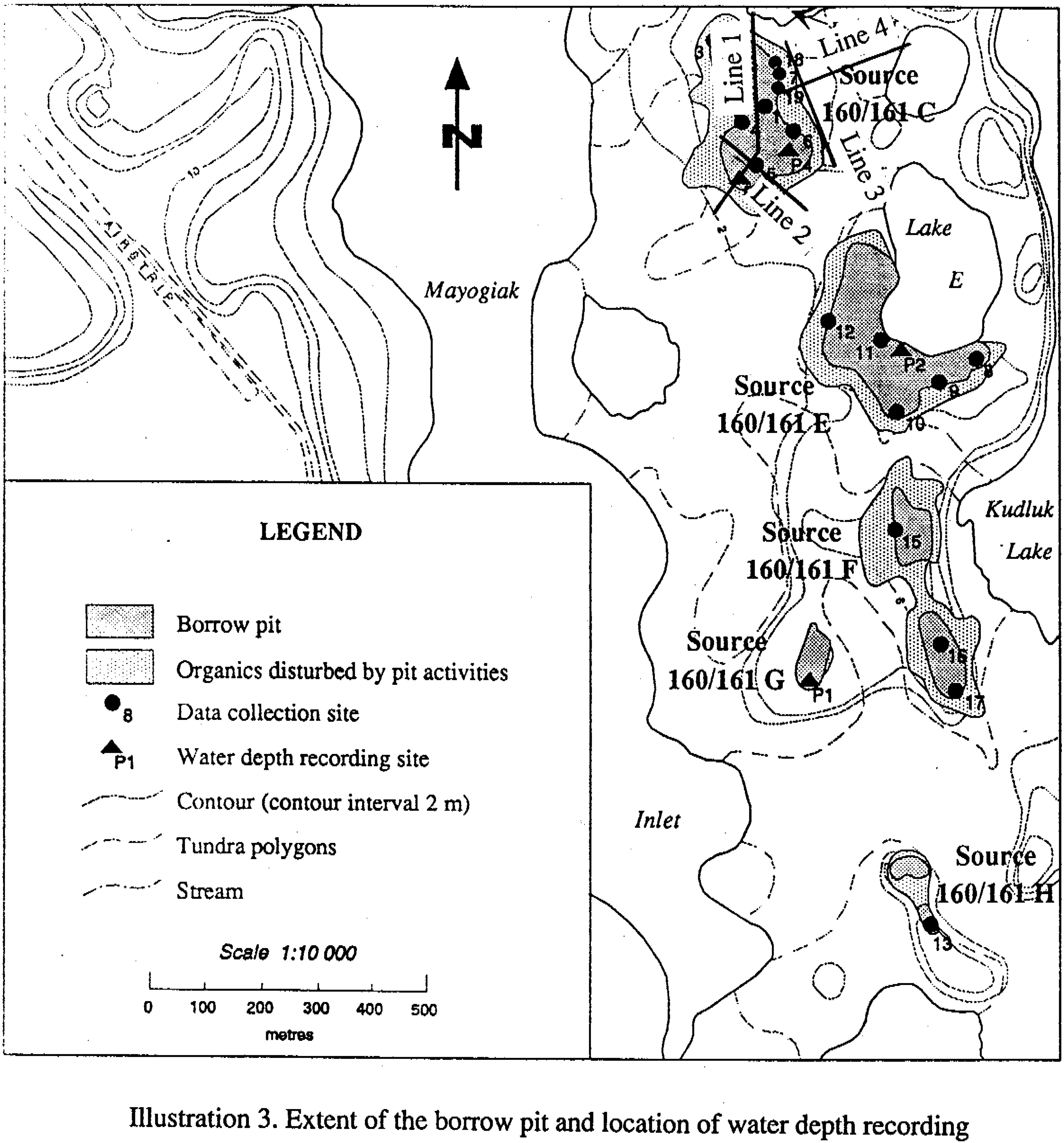


Illustration 3. Extent of the borrow pit and location of water depth recording sites, data collection sites and grid survey lines at Source 160/161C (modified after Thompson 1992).

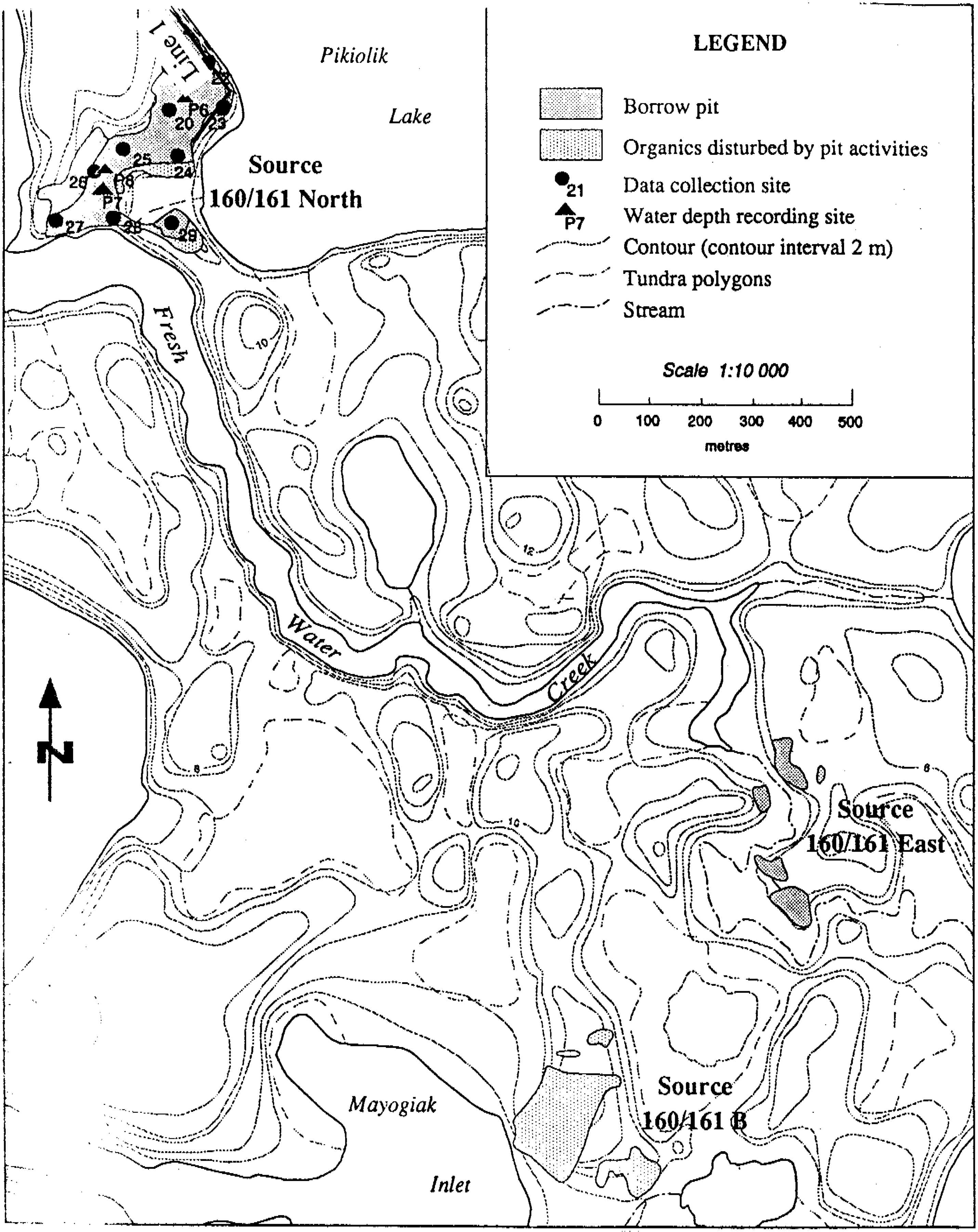


Illustration 4. Extent of the borrow pit and location of water depth recording sites, data collection sites and grid survey lines at Source North (modified after Thompson 1992).

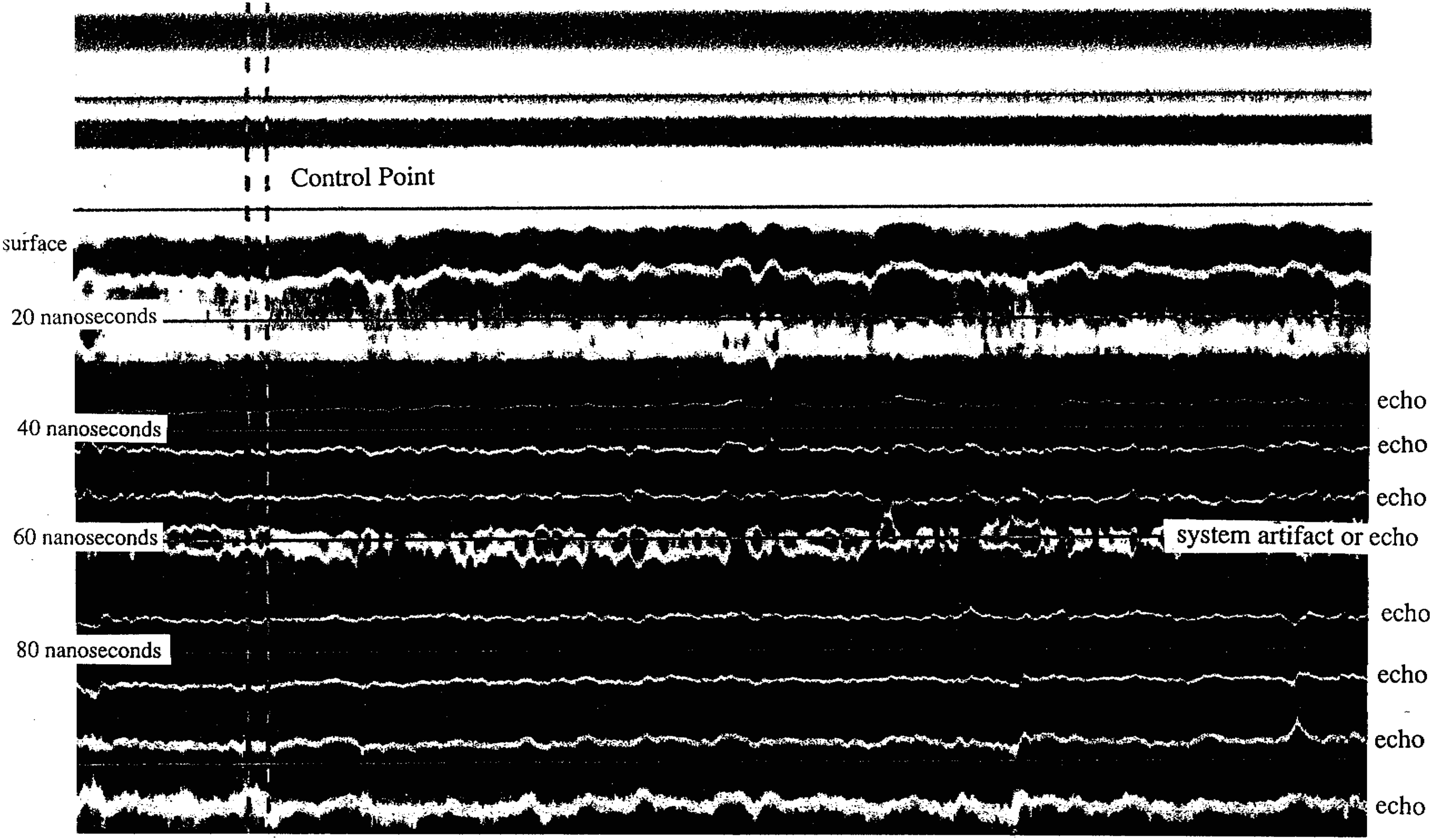


Illustration 5. Example of a terrestrial profile record, Source A, Line 1.

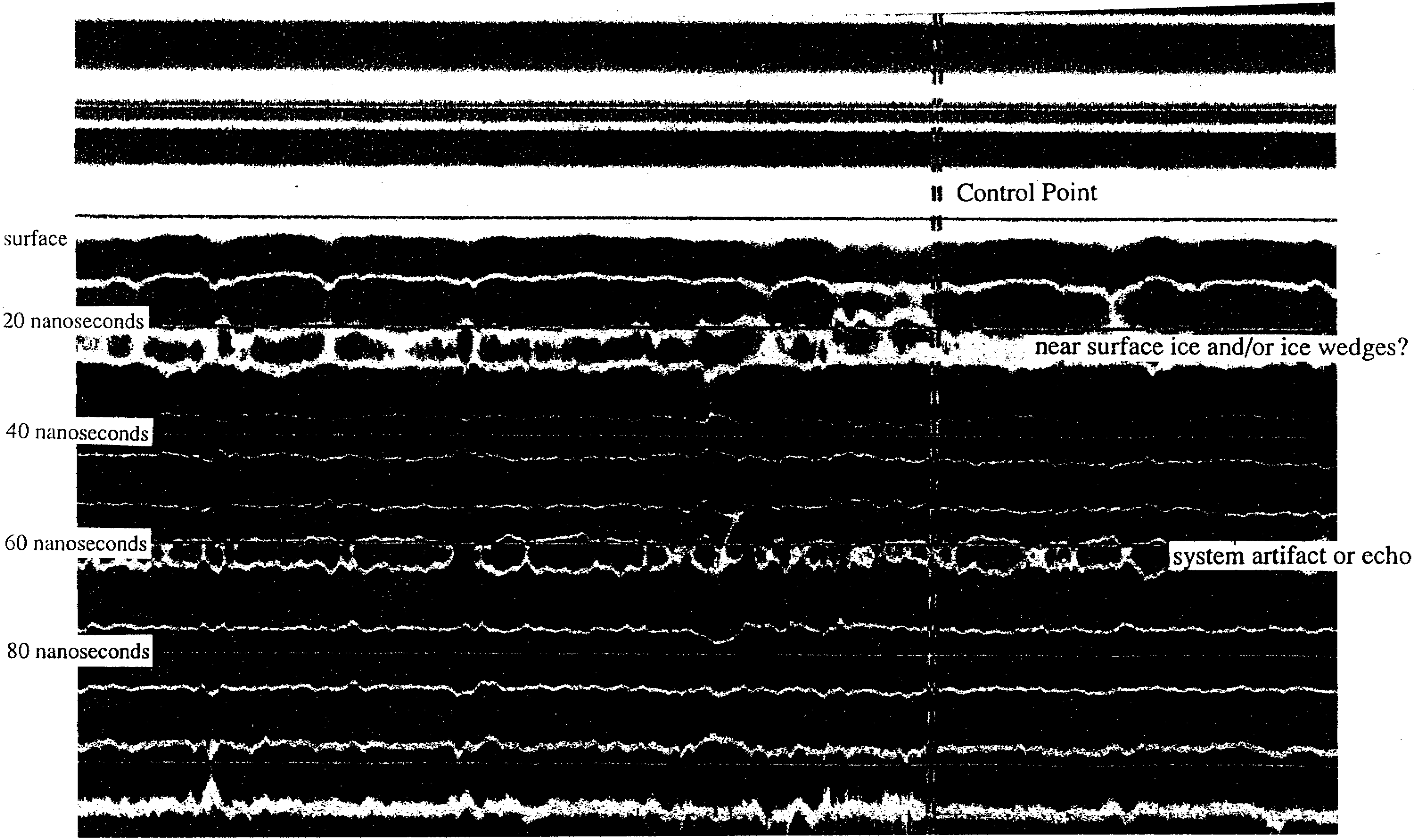


Illustration 6. Profile record from undisturbed terrain east of the borrow pit at Source C, Line 4.

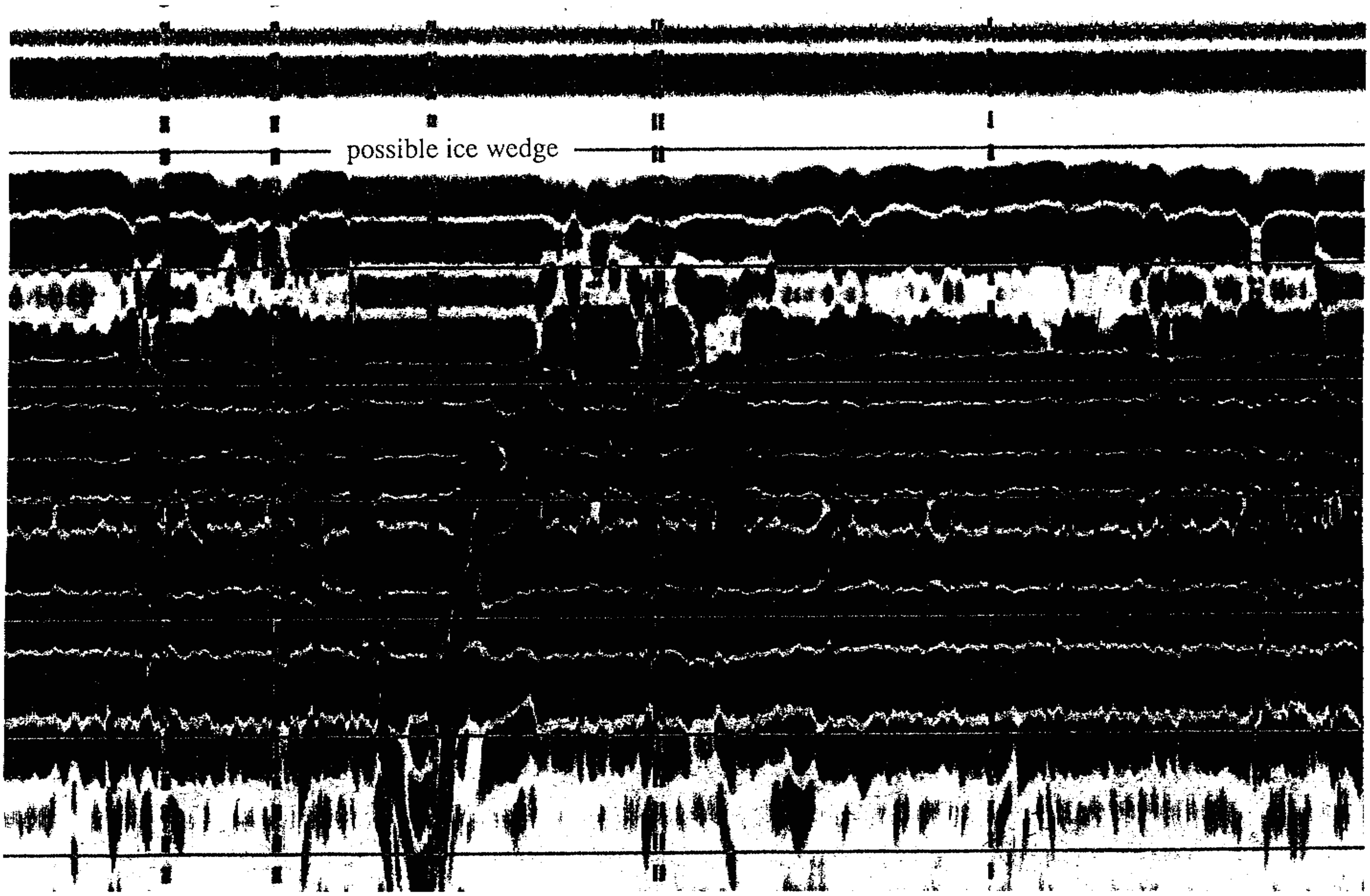


Illustration 7. Profile record from the ridge west of Pikiolik Lake, Source North, Line 1

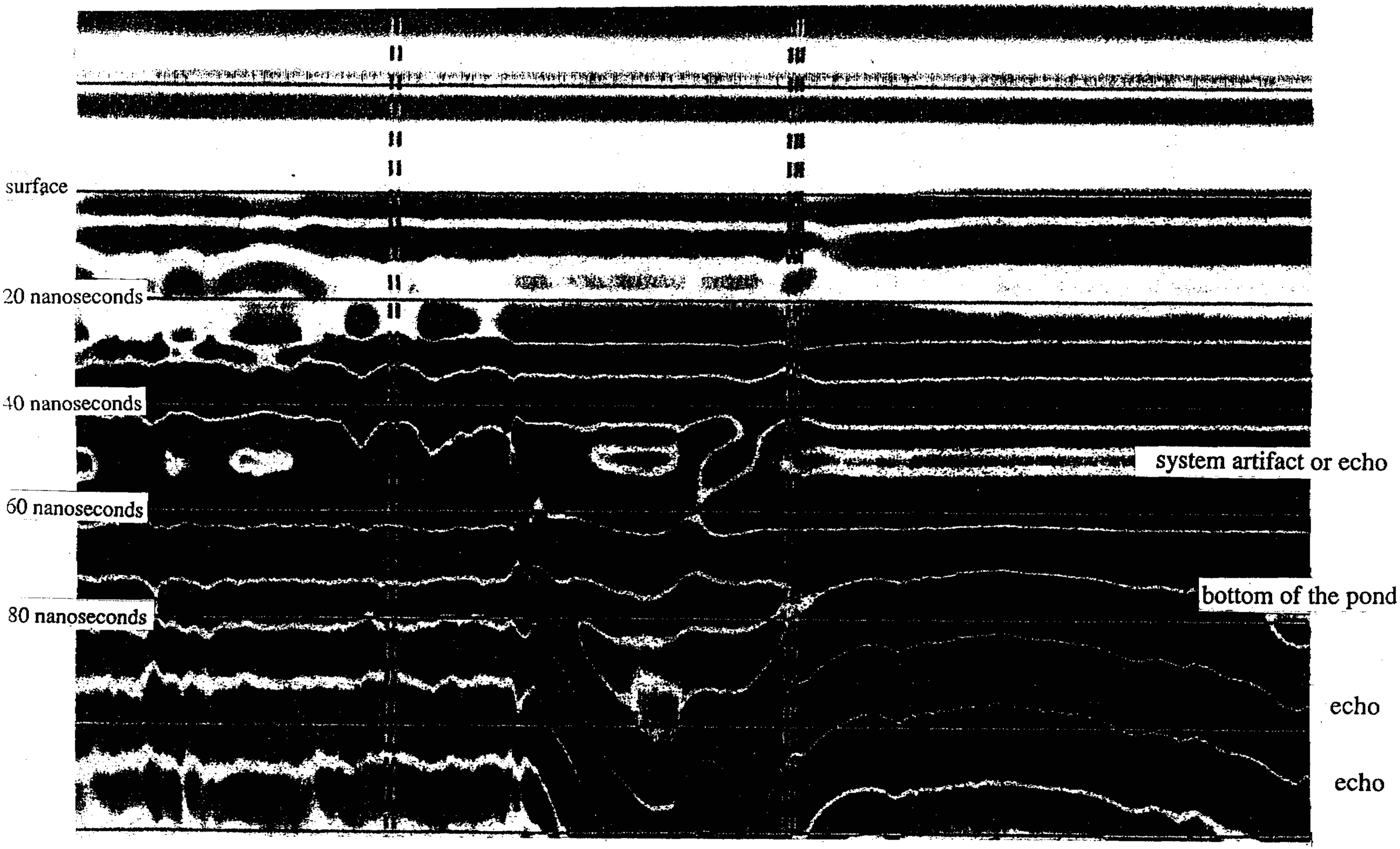
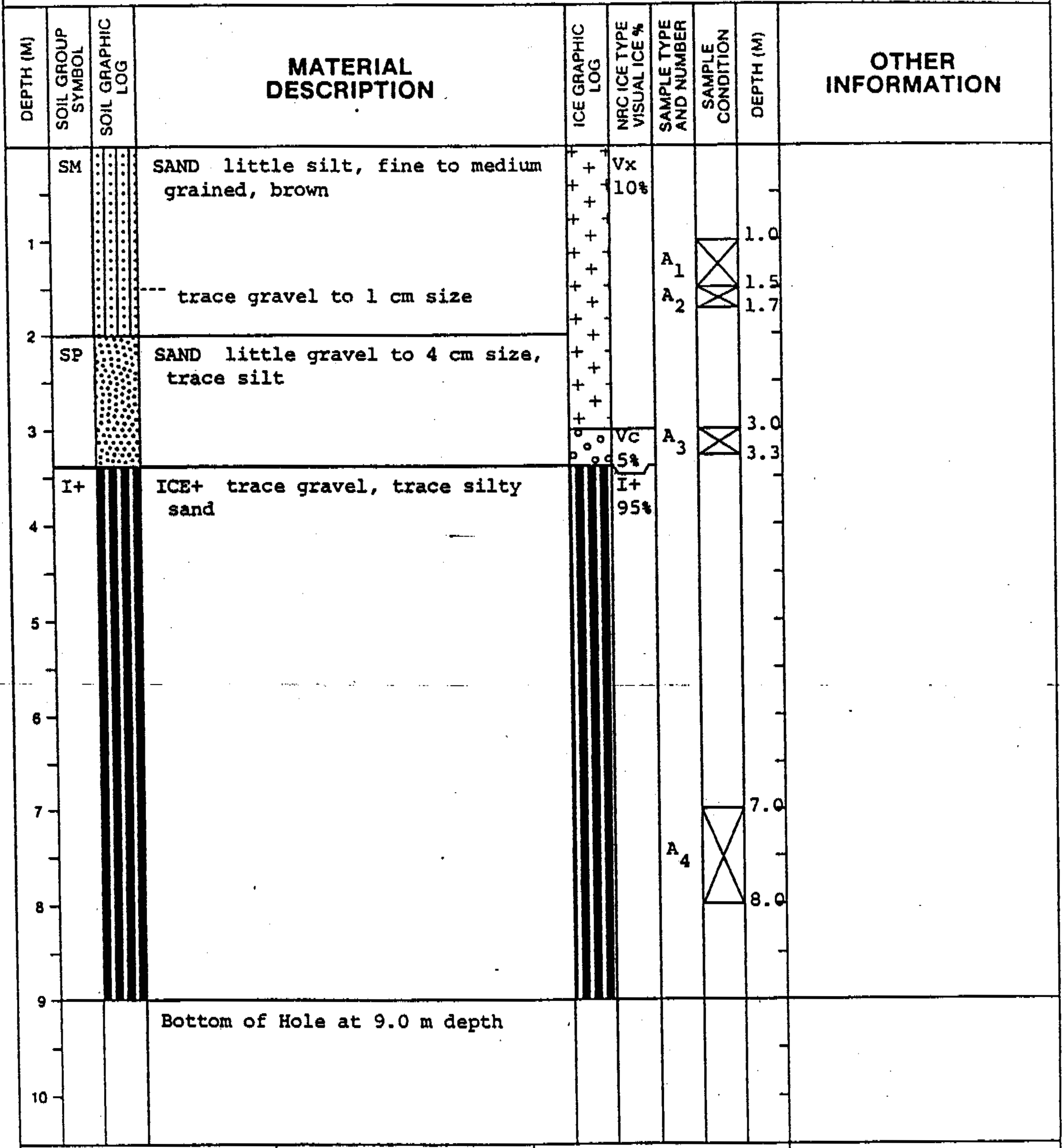


Illustration 8. Example of a lacustrine profile record, Source C, Line 1.

APPENDIX B
BOREHOLE LOGS

TEST HOLE LOG 1



SOIL GROUP SYMBOL	MATERIAL DESCRIPTION	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	DEPTH (M)
SM	SAND little silt, fine to medium grained, brown	Vx 10%		
			A_1	1.0 1.5
	--- trace gravel to 1 cm size		A_2	1.5 1.7
SP	SAND little gravel to 4 cm size, trace silt	Vc 5%	A_3	3.0 3.3
I+	ICE+ trace gravel, trace silty sand	I+ 95%		
			A_4	7.0 8.0
	Bottom of Hole at 9.0 m depth			

DATE: 80.01.21	LOGGED BY: G.D.	DRWN BY: C.G.	CHKD BY: N.H.

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TEST HOLE NO.
1

TEST HOLE LOG 2

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
	Pt		PEAT		Vr 40%				
	I+		ICE+ trace silt		I+ 90%	A_1	☒	1.0 1.3	
1	SM		SAND little silt, fine grained, brown		Vx 10%	A_2	☒	2.0 2.3	
2 3 4	SP		SAND fine grained, trace silt, trace coarse sand to 0.5 cm size		Nbe	A_3	☒	4.0 4.3	
5 6 7	I+		ICE+ trace sand		I+ 90%				
8	SP		SAND fine to medium grained, light brown		Vc- Vx 30%	A_4	☒	8.5	
9 10			Bottom of Hole at 9.0 m depth						

DATE: 80.01.21	LOGGED BY: G.D.	DRWN BY: C.G.	CHKD BY: N.H.

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TEST HOLE NO.
2

TEST HOLE LOG 3

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
	Pt		PEAT		Vr 30%				
	SM		SAND little silt, fine grained, brown	+	Vx 20%	A_1	☒	1.4 1.6	
	I+		ICE+ trace sand		I+ 90%				
	SP		SAND fine to medium grained, occasional coarse sand sizes	+	Vx 15%	A_2	☒	5.5 6.0	
	I+		ICE+ little sand		I+ 80%	A_3	☒	7.2 7.4	
	SP		SAND fine to medium grained, occasional coarse sand sizes	+	Vx 40%	A_4	☒	8.2 8.6	
	I		ICE		I				
			Bottom of Hole at 9.0 m depth						

DATE: 80.01.21	LOGGED BY: G.D.	DRWN BY: C.G.	CHKD BY: N.H.

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TEST HOLE NO.
3

TEST HOLE LOG 4

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
	Pt		PEAT		Vr 30%				
	GP		GRAVEL and fine to coarse sand, trace silt, rounded to subrounded, to 4 cm size, poorly graded, brown	+	Vx 10%	A_1	☒	0.3 0.6	Grain Size (A-43) w = 10.9%
1	SP		SAND and rounded to subrounded gravel to 4 cm size, trace silt, fine to coarse grained, poorly graded, brown	+		A_2	☒	1.5 2.0	Grain Size (A-44) w = 15.8%
2			--- trace gravel to 4 cm size	+		A_3	☒	2.5 2.8	Organic Colour: #3+ Grain Size (A-45) w = 23.4%
3			trace gravel to 3 cm size	+		A_4	☒	3.2 3.4	w = 21.0%
4	GP		GRAVEL some fine to coarse sand, trace silt, to 10 cm cobble size, rounded, poorly graded	+	Nbn	A_5	☒	3.8 4.0	Grain Size (A-46) w = 9.1%
5						A_6	☒	4.7 5.0	w = 15.4%
6 7	I+		ICE+ trace silty sand		I+ 90%				
8 9 10			Bottom of Hole at 8.0 m depth						

DATE: 80.01.21	LOGGED BY: G.D.	DRWN BY: C.G.	CHKD BY: N.H.

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TEST HOLE NO.
4

TEST HOLE LOG 17

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
	SM		SAND some silt, little gravel to 3 cm size, dry		Nf				
			trace gravel to 1 cm size			A_1	☒	0.6 0.9	
1									
			fine to medium grained, little silt		Nbn				
2									
						A_2	☒	2.8 3.0	
3									
			little gravel to 2 cm size, occasional cobbles to 8 cm size, little silt						
4						A_3	☒	4.3 4.4	
	I		ICE		I				
5									
6									
7			Bottom of Hole at 6.5 m depth						
8									
9									
10									

DATE: 80.01.26	LOGGED BY: G.D.	DRAWN BY: C.G.	CHKD BY: N.H.

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TEST HOLE NO. 17

TEST HOLE LOG 18

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
	SP		SAND trace silt, occasional pebbles to 1 cm size, fine to medium grained		Nf	A$_1$	☒	0.8 0.9	
1			--- trace gravel to 6 cm size, rounded --- no gravel						
2	I+		ICE+		I+ 95%				
3									
4			Bottom of Hole at 4.0 m depth						
5									
6									
7									
8									
9									
10									

DATE: 80.01.26	LOGGED BY: G.D.	DRWN BY: C.G.	CHKD BY: N.H.

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS
AND
NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
18

TEST HOLE LOG 19

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
1	SP		SAND and rounded gravel to 3 cm size, little silt, fine to coarse grained, poorly graded, dry to 1.0 m depth		Nf	A_1	⊠	0.6 0.8	Organic Colour: #5+ Grain Size (A-60) w = 14.1%
2			└- trace silt		Nbn	A_2	⊠	1.6 1.8	Grain Size (A-61) w = 14.4%
3	SM		SAND little gravel to 5 cm size, little silt			A_3	⊠	2.8 3.0	Grain Size (A-62) w = 22.4%
			-- some gravel to 3 cm size			A_4	⊠	3.5 3.6	w = 11.6%
4 5	I+		ICE+ trace sand		I+ 95%				
6 7 8 9 10			Bottom of Hole at 6.0 m depth						

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TEST HOLE NO.
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