83-#678 - 11845

10/84

HELICOPTER INPUT E.M. SURVEY

KETTLE RIVER RESOURCES LTD.

SYLVESTER K - PHOENIX PROJECT

YOUNG GEORGE PROJECT

BRITISH COLUMBIA

PROJECT NO: 25H52 OCTOBER, 1983

Part 1 of 2

Questor Surveys Limited, 6380 Viscount Road, Mississauga, Ontario L4V 1H3

C O N T E N T S

INTRODUCTION

i) Area Location

This report contains the results and interpretation for a Helicopter MK VI INPUT E.M. Survey which was carried out in the Sylvester K-Phoenix and Eholt areas, British Columbia. In particular, the survey involved the flying of several test lines, over and to the north of the old Phoenix Mines, as well as in an area referred to as the Young George Project. The flying operations for both areas were carried out from Nelson which is located approximately 50 kilometres to the northeast of the survey area. Grand Forks was used as a refuelling base.

ii) Dates Flown

The survey was performed on October 6, 1983 when the weather was clear with visibility unlimited. The total survey time, including ferrying to the area and back to Nelson, took 2.6 hours. The actual time on survey was 0.5 hours.

iii) Survey Mileages

The total measured line mileage was 21.6 kilometres with 7.2 kilometres flown in the Sylvester K-Phoenix area, and 14.4 kilometres in the Young George area. The survey was performed by QUESTOR SURVEYS LIMITED of Mississauga, Ontario utilizing a Bell 205 Helicopter as the survey platform.

iv) Area Outline

An area outline for the survey areas is located at the end of the interpretative section of this report, just ahead of the Appendices. The scale of this map is 1:250,000 and is part of the National Topographical Series, sheet number 82E, Penticton.

v) Personnel

The following were the personnel involved with the airborne survey operations:

Pilot	-	Bob Masson
Navigators	-	Harold Sandau
Electronic Technician/ Operator	-	Keith Higgenbottam
Maintenance Engineer	-	Laughin Currie
Project Geophysicist	-	Simon Wong

The personnel involved with the data compilation at QUESTOR SURVEYS' Mississauga, Ontario office were as follows:

Data Reduction	-	Jim Gray
Drafting	-	Cheryl Jordan
Photography	-	Don Thurston
Computer Processing	-	John Charlton

All aspects of the data compilation process were supervised by Robert deCarle, Chief Geophysicist, who also carried out the reporting and interpretation of the results.

SURVEY PROCEDURES

i) Flying Methods

A terrain clearance of 122 metres was maintained over much of the survey area but for reasons of safety, there were times when the Helicopter was in excess of this altitude. Where there were extremely narrow crevices or valleys where the Helicopter could not drape fly, distance between aircraft and ground will certainly exceed 122 metres. The Bird or receiving coil will, in most cases, be approximately 45 metres above the ground. The Helicopter flew the flight lines using a normal S-pattern flight path with an approximate one half kilometre turn. The lines were flown consecutively and in alternate directions for the sole purpose of interpreting dipping conductors. The INPUT system gives characteristic responses, which are very diagnostic in qualitative interpretation, when the conductor is flown in the up-dip direction. This phenomenon will be dealt with later.

ii) Line Spacing

A variable spacing was used for the purpose of testing known occurrences, resulting in a line spacing of approximately 250 metres in the Sylvester K-Phoenix area and a line spacing of approximately 380 metres in the Young George area.

iii) Flight Direction

The flight direction for Sylvester K-Phoenix area was generally in a northwest-southeast direction but varies because of the necessity of obtaining maximum electromagnetic coupling for each of the conductors. In the Young George area, the direction was generally northeast-southwest for the same reasons given previously.

iv) Equipment Operations

The equipment operator or electronic technician logged the details of flight and monitored the equipment on board the Helicopter. Such details as the start time for each line, first and last fiducial marker, weather problems and any other pertinent information relating to the flight have been recorded on Flight Logs. These have been included in the final shipment. It was the responsiblity of the Project Geophysicist to maintain and check the ground magnetic base station, which is a Geometrics G-826, for violent variations in daily diurnal. Because of its effect on the levelling of the magnetics, QUESTOR set a limit of 20 gammas over 5 minutes. However, there may have been time spans when this limit has been exceeded. However, these would be over a very short time. These recordings have been included in the final shipment.

MAP COMPILATION

i) - Base Maps

The base map for the Sylvester K-Phoenix area, used for navigation and flight path recovery, was a photographic transparency at an approximate scale of 1:10,000 which were made from 1979, 1:20,000 photographs obtained from the British Columbia Air Photo and Map Office. The photographs for the Young George area were at a scale of 1:16,000. The final base maps which contain the INPUT results were reproduced at a scale of 1:10,000 on stable transparent film from which white prints can be made. Only one map sheet was necessary for each of the survey areas and a copy of these map layouts is located on the right hand side of each map sheet, just above the title block. Reference to these areas is facilitated with the labelling of longitudes and latitudes as well as the National Topographic Series Numbers.

ii) Path Recovery

The flight path recovery was accomplished by comparing the topographical features on the 35 mm. half-frame film with the photomosaic base maps. The fiducial or timing markers on the film, which correlates with these known points, are then transferred onto the photomosaic. As many identifiable fiducial points as possible are plotted onto the base maps and as such, most picked points are between 250 metres and 500 metres, depending on the difficulty of the area. Some picked points are much in excess of this figure and this is due to extensive areas being covered with trees. Therefore, navigational features and thus, recovery points are limited.

DATA PRESENTATION

The results of the Helicopter MARK VI INPUT Survey are presented to the client in the following manner:

- 2 blank photographic base maps;
- 2 photographic base maps showing combined INPUT anomalies, magnetic associated peaks, flight lines, interpretation and selected targets at a scale of 1:10,000;
- 4 interpretative reports with white prints of the final maps.

See Appendix E for a comprehensive description of the interpretational approach used in Helicopter INPUT surveys.

QUESTOR'S conventional form for presenting the Helicopter INPUT data on a base map is self-explanatory and is located in the upper right hand corner of each map.

SYLVESTER K - PHOENIX AREA

The test lines in this area were flown over the former Phoenix Mine which was owned by Granby Mining Corporation which, in 1979, amalgamated with two other companies to form Zapata Granby Corp. Later that same year, the latter company was taken over by Noranda Mines Limited which is thought to still control the Phoenix Mines property at this time. The property was a low grade copper-gold mine operating from 1959 and lasted until 1976 when ore reserves were exhausted.

The copper mineralization occurs as disseminations of chalcopyrite in limy rocks and to a lesser extent in massive magnetite lenses injected between limy sedimentary rocks and footwall argillite. Gold and silver occur in solid solution and as minute blebs in pyrite and chalcopyrite grains. As of December 31, 1974, ore reserves were calculated to be 963,410 tons of ore, grading 0.807 per cent copper.

A number of broad, strong responses were intercepted in this area during the course of flying these five flight lines. The broadness of the intercepts suggests a relatively wide zone of mineralization with intercepts 10100C to E enveloping the northern limits of the Phoenix open pit, and intercepts 10500A to B possibly indicating a northerly extension of this mineralization which was the basis for the former Phoenix Mines. This wide zone of mineralization appears to be a zone shallowly dipping to the east. Other conductors indicated on the map are interpreted to be stringer type or vein type zones and form an entirely different E.M. response than the main zone. Note the absence of any magnetics with the main, wide zone. Sulphides, mainly pyrite, is the probable cause.

It is suggested that a ground reconnaissance survey be carried out, certainly on the northerly extension of the main zone but also, on the single conductive trend immediately to the west of this main zone.

YOUNG GEORGE AREA

Two areas were flown with Helicopter INPUT E.M. on this project; one approximately 2.4 kilometres south of Eholt and the other roughly 1.5 kilometres north of Eholt. The area to the south of Eholt, in fact, would appear to be close to the same area as the Oro Denoro copper deposit. "The Oro Denoro and its neighbours formed the Summit Camp of the Boundary copper district. The Summit Camp produced some 632,000 tons of ore, of which 136,477 tons is recorded as having come from the Oro Denoro."

The Oro Denoro is underlain by Triassic sharpstone conglomerate, tuffaceous sediments, minor limestone, and fine-grained volcanic breccias intruded by a succession of granitic rocks ranging in age from that of the Lower Cretaceous Nelson intrusions to the Paleocene Coryell intrusions. There is an extensive development of skarn, chiefly epidote-garnet-calcite, which appears to have been derived both from the tuffaceous rocks and from the older intrusive rocks.

The mineralization is chalcopyrite and pyrite. Predominantly, it is associated with skarn. Magnetite and pyrrhotite are reported in ores produced from different sections of the property but neither was recognized in the original drillings.

There were definitely some interesting anomalies intercepted on these two flight lines which could very well be associated with sulphides. However, caution should be implemented for those responses which correlate with the road (Highway 3). Even though there were no responses or indications on the hydro monitor that 60 Hz existed, this source may, in fact, be the cause. Otherwise, the writer's interpretation for this area is that there exists three separate conductors. The most westerly, CONDUCTOR A, displays very good conductivity and is correlating with the eastern flank of a relatively high intensity magnetic feature. This suggests the possible association with a geological contact. Referring to the photomosaic, it will be noted that there exists an open pit just to the west of the highway, adjacent to the railway tracks. The high intensity magnetic feature correlates with this pit and continues well to the north to at least flight line 12320W. Magnetite, no doubt, is the cause. CONDUCTOR A is interpreted to be dipping to the east and is probably located within 10 metres of surface. The amount of dip is possibly 70°. Although intercept 12320A is interpreted to be along strike, its response is very weak and is rather difficult to obtain any qualitative information.

CONDUCTOR B, on the other hand, displays somewhat weaker electromagnetic responses but is still due to a bedrock source. Intercept 12310B is interpreted to be the up-dip indicator suggesting an approximate 80° dip to the east. The magnetic correlation between 30 and 33 gammas suggests that pyrrhotite may be the source.

Intercept 12320A, or CONDUCTOR C, displays a very weak electromagnetic response but is still considered to be related to a bedrock source. Note the magnetic association. Minor amounts of pyrrhotite may be the source which is the cause of this weak anomaly.

The two flight lines which were flown north of Eholt were flown partly along the north slope and partly across the top of a northeast striking ridge. Viewing the aerial photographs, there does not appear to be any workings (mineral prospects) along the flight lines, so that information on this particular area is not available to the writer. There is a clearing at fiducial 143 but the writer is unaware of what may be in this area. There has been a considerable amount of activity within the general region but, in particular, not in this area. The B.C. Mine of Granby Mining Co. Ltd. and the Stan Mineral claims are two such areas. Further to the west, just southeast of Jewell Lake, is the gold-silver property of Dentonia Resources Ltd. Development work is presently underway on this ground.

The writer is unaware of the underlying geology which the flight lines were flown over.

As one can observe on the analogue charts, there was a total of three very weak one-channel responses intercepted on the two flight lines, 60351W and 60352E. They are interpreted to be caused by weakly conducting overburden or possibly structural effects; ie. fault zones, shear zones or geological contacts. However, the writer believes they more than likely are due to the former. They are definitely not related to sulphides. Further work in this area, based solely from a base metal point of view, is not recommended.

Respectfully submitted,

QUESTOR SURVEYS LIMITED,

R. J. de Carle

R.J. deCarle,
Chief Geophysicist.

RJdC/djd

References

Minister of Mines and Petroleum Resources, Province of British Columbia, Annual Report 1965;

Minister of Mines and Petroleum Resources, Province of British Columbia, Annual Report 1966;

Geology, Exploration and Mining in British Columbia, 1974;

Geology, Exploration and Mining in British Columbia, 1978.

Christian Valley
Maloney
BLUEJOINT MTN
MT FRANKLIN
MT McKINLEY
GABLE MTN
TERRACED PEAK
BUNCH-GRASS HILL
MT FAITH
ALMOND MTN
MIDWAY RANGE
MONASHEE MTS
CHRISTINA RANGE
Williamson Ck
Blythe Ck
Crowe Creek
Kennedy Ck
MOUNT RODERICK DHU
MT PEULY
Eholt
Wallace Creek
DEADWOOD RIDGE
COPPER MTN
THIMBLE MTN
Toronto Ck
Xenia L.
INGRAM RIDGE
Greenwood
Fisherman
Anaconda
Boundary Falls
MT ATTWOOD
MOUNT MORRISSEY
Grand Forks
West Grand Forks
West Midway
Midway
Billings

APPENDIX A

BARRINGER/QUESTOR MARK VI INPUT(R) Helicopter System

The INduced PUlse Transient (INPUT) method is a system whereby measurements are made, in the time domain, of a secondary electromagnetic field while the primary field is between pulses. Currents are induced into the ground by means of a pulsed primary electromagnetic field which is generated from a transmitting loop around the helicopter. By using half-sine wave current pulses (Figure A-1) and a transmitter loop of large turns-area, a high signal-to-noise ratio and the high output power needed for deep penetration, are achieved.

Induced current in a conductor produces a secondary electromagnetic field which is detected and measured after the termination of each primary pulse. Detection of the secondary field is accomplished by means of a receiving coil, wound on an air core form, mounted in a PCV plastic shell called a "bird" and towed behind and below the helicopter on 76 metres (250 feet) of coaxial cable. The received signal is processed and recorded by equipment within the helicopter.

The axis of the receiving coil may be vertical or horizontal relative to the flight direction. In rolling or hilly terrain the standard or horizontal coil axis is preferred, although in steep terrain, the vertical axis coil optimizes coupling with horizontal or dipping stratigraphy. The secondary field is in the form of a decaying voltage transient, measured in time, at the termination of the primary transmitted pulse. The amplitude of the transient is proportional to the amount of current induced into the conductor, the conductor dimensions, conductivity and the depth beneath the helicopter.

The rate of decay of the transient is inversely proportional to conductance. By sampling the decay curve at six different time intervals and recording the amplitude of each sample, an estimate of the relative conductance can be obtained. Transients due to strong conductors such as sulphides and graphite, usually exhibit long decay curves and are therefore commonly recorded on all six channels. Sheet-like surface conductive materials, on the other hand, have short decay curves and will normally only show a response in the first two or three channels.

For homogeneous conditions, the transient decay will be exponential and the time constant of decay is equal to the time difference at two successive sampling points divided by the log ratio of the amplitudes at this point.

TRANSMITTER SPECIFICATIONS

Pulse Repetition Rate	211	per sec
Pulse	Half sine	
Pulse Width	2.0	millisec
Off Time	2.7	millisec
Output Voltage	60	volts
Output Current Peak	235	amperes
Output Current RMS	106	amperes
Output Current Average	60	amperes
Coil Area	167 $m.^2$ ($1,800\ ft.^2$)	
Coil Turns	6	
Electromagnetic Field Strength (peak)	233,800	amp-turn-$meter^2$

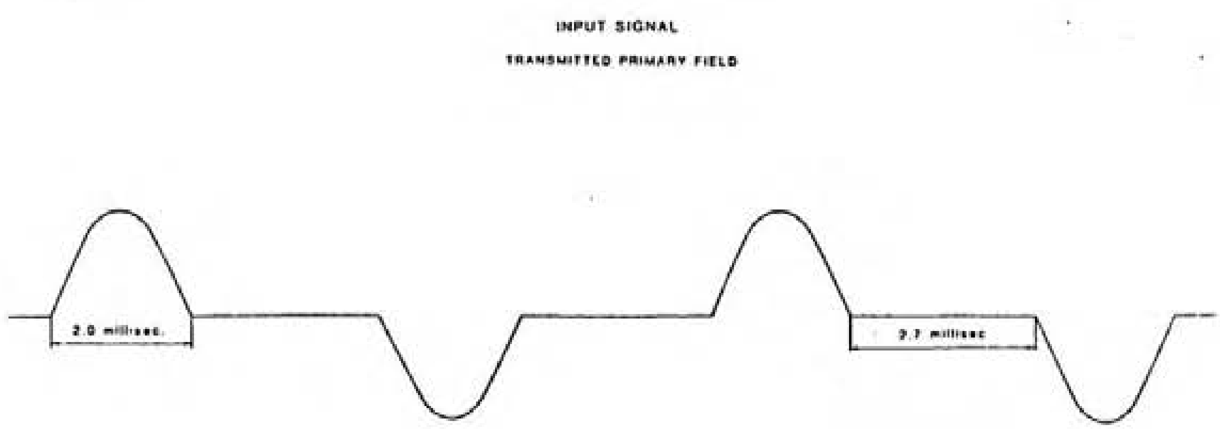


Figure A1

TRANSMITTER SPECIFICATIONS

Pulse Repetition Rate	180	per sec
Pulse	Half sine	
Pulse Width	2.0	millisec
Off Time	2.7	millisec
Output Voltage	67	volts
Output Current Peak	200	amperes
Output Current Average	55	amperes
Coil Area	177 $m.^2$ ($1,904\ ft.^2$)	
Coil Turns	7	
Electromagnetic Field Strength (peak)	247,800	amp-turn-$meter^2$

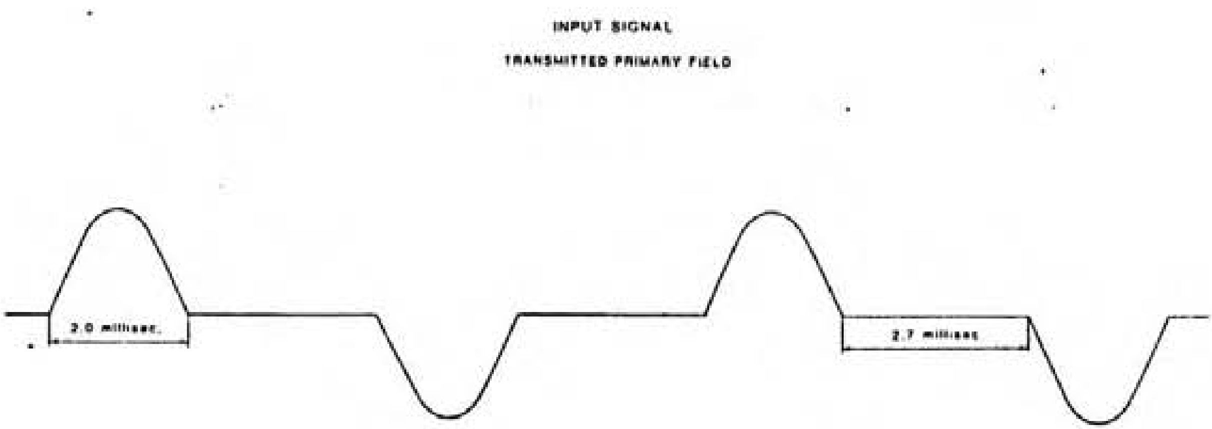


Figure A1

RECEIVER SPECIFICATIONS

Sample Gate	Windows (centre positions)	Widths
CH 1	340 sec	200 sec
CH 2	540	200
CH 3	840	400
CH 4	1240	400
CH 5	1740	600
CH 6	2340	600

Sample Interval	0.5 sec
Integration Time Constant	1.3 sec
Bird Position behind Aircraft (at 40 kt)	19 metres
Bird Position below Aircraft (at 40 kt)	73 metres

Receiver features: Power Monitor 50 or 60 Hz

50 or 60 Hz and Harmonic Filter

VLF Rejection

Spheric Rejection (tweak) Filter

SAMPLING OF INPUT SIGNAL

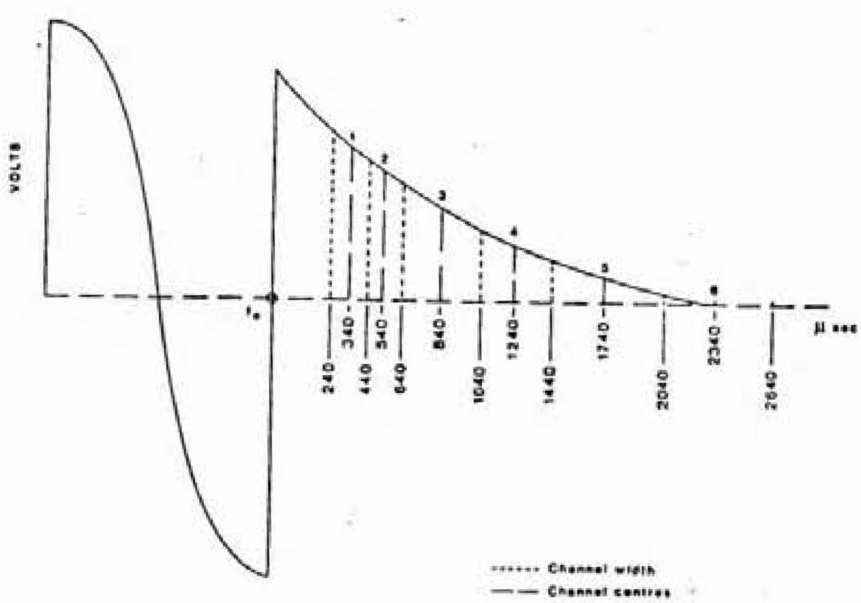


Figure A2

DATA ACQUISITION SYSTEM

Sonotek SDS 1200

9 track 800 BPI ASCII

Includes time base Intervalometer, Fiducial System

CAMERA

Geocam 75 SF

35 mm continuous strip or frame

TAPE DRIVE

Digidata Model 1139

OSCILLOSCOPE

Tektronix Model 305

ANALOG RECORDER

Honeywell Visicorder WS 4010

Kodak Light Sensitive Pape (15cm)

Recording 14 Channels: 50-60 Hz Monitor, 6 INPUT Channels, fine and coarse Magnetics, Altimeter, vertical and horizontal timing lines and fiducial markers.

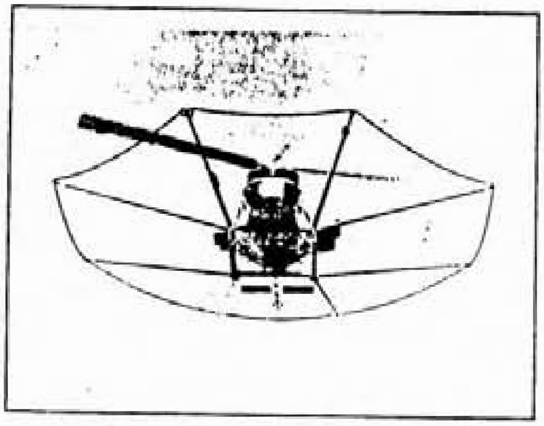
ALTIMETER

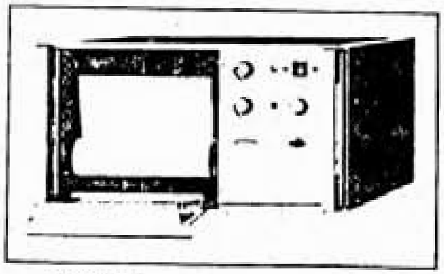
Sperry Radar Altimeter

SONOTEK P.M.H. 5010 PROTON MAGNETOMETER

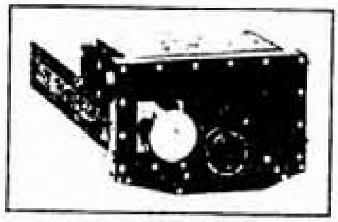
The airborne magnetometer is a proton free precession sensor, which operates on the principle of nuclear magnetic resonance to produce a measurement of the total magnetic intensitity. It has a sensitivity of 1 gamma and an operating range of 20,000 gammas to 100,000 gammas. The sensor is a solenoid type, oriented to optimize results in a low ambient magnetic field. The sensor housing is mounted on the tip of the nose boom supporting the INPUT transmitter cable loop. A 3-term compensating coil and perma-alloy strips are adjusted to counteract the effects of permanent and induced magnetic fields in the aircraft.

Because of the high intensity electromagnetic field produced by the INPUT transmitter, the magnetometer and INPUT results are sampled on a time-share basis. The magnetometer head is energized while the transmitter is on, but a measurement is only obtained during a short period when the transmitter is off. Using this technique, the sensor head is energized for 0.80 seconds and subsequently the precession frequency is recorded and converted to gammas during the following 0.20 seconds when no current pulses are induced into the transmitter coil.

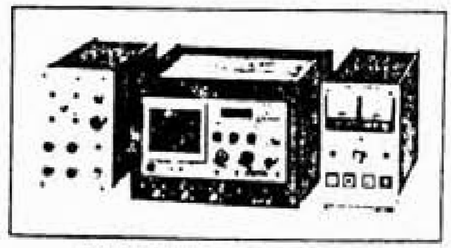




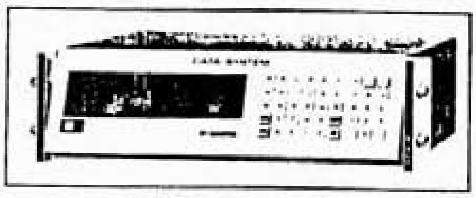
HONEYWELL ANALOGUE CHART RECORDER



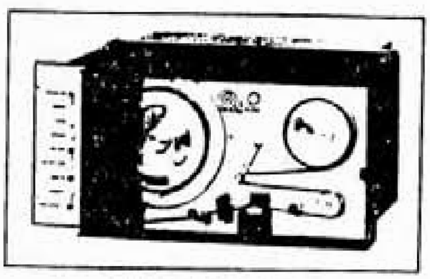
35mm TRACKING CAMERA



INTERFACE, OSCILLOSCOPE & T.C.U.

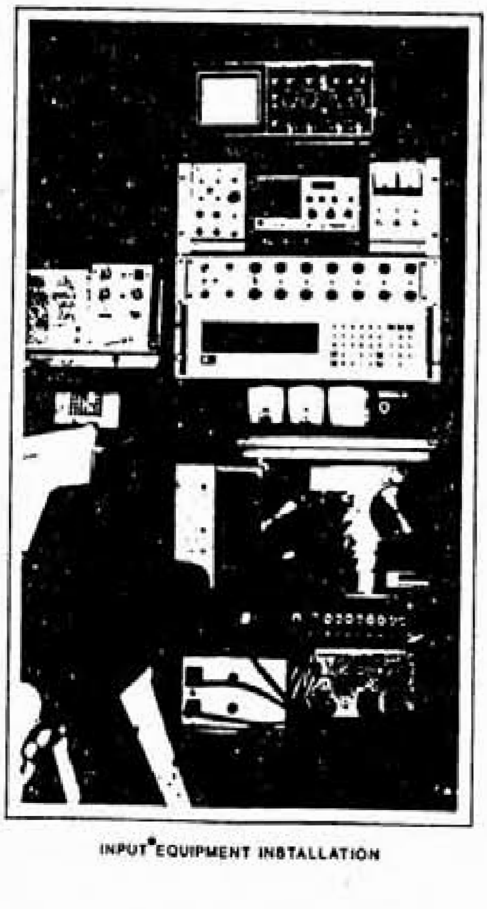


SONOTEK DATA SYSTEM

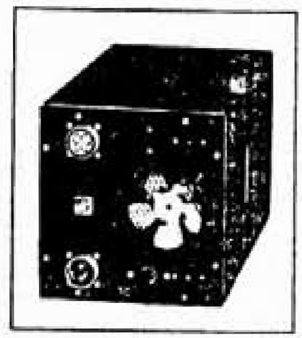


8 TRACK TAPE RECORDER

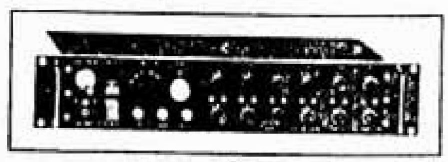
RADAR ALTIMETER



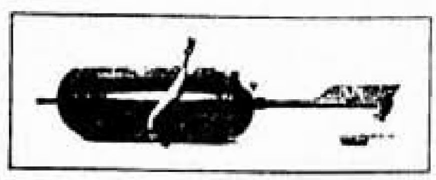
INPUT® EQUIPMENT INSTALLATION



TRANSMITTER



MK VI INPUT® RECEIVER



TOWED "BIRD" ASSEMBLY

QUESTOR/BARRINGER MARK VI "INPUT"® SYSTEM EQUIPMENT

APPENDIX B

The Survey Helicopter

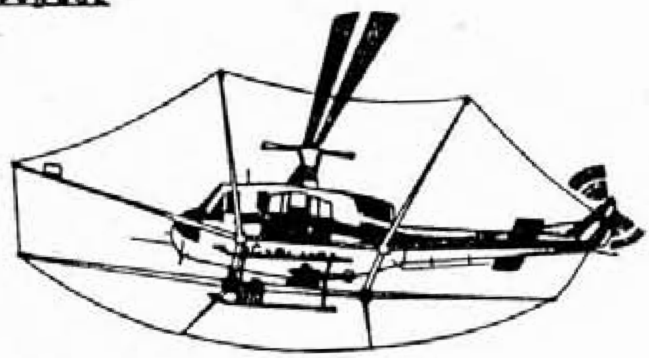


Figure B1

Manufacturer	Bell Helicopter Company
Type	205A-1
Canadian Registration	C-GLMC - present installation
Date of INPUT Installation	May 1982

Modifications:

1) Cradle and wing booms for transmitter coil mounting
2) Camera and altimeter mounting
3) Modified gasoline driven generator system

Any BELL 205-212 airframe can support the QUESTOR Helicopter INPUT system. The 205 is powered by one low maintenance turbine engine. The configuration of the helicopter provides for easy installation of equipment, which can be dissasembled and crated to the survey base. Reassembly takes less than two days. These factors have proven the helicopter to be a reliable and efficient geophysical survey system in areas not suitable for fixed-wing operation.

APPENDIX C

INPUT System Characteristics

a) Geometry

The INPUT system, a time domain airborne electromagnetic system, has the transmitter loop located around the helicopter airframe while the receiver, referred to as the 'bird', typically is towed 19 metres behind and 73 metres below the helicopter at a survey airspeed of 40 knots. The actual spatial position of the bird is dependent on the airspeed of the survey helicopter, as can be seen in Figure C1.

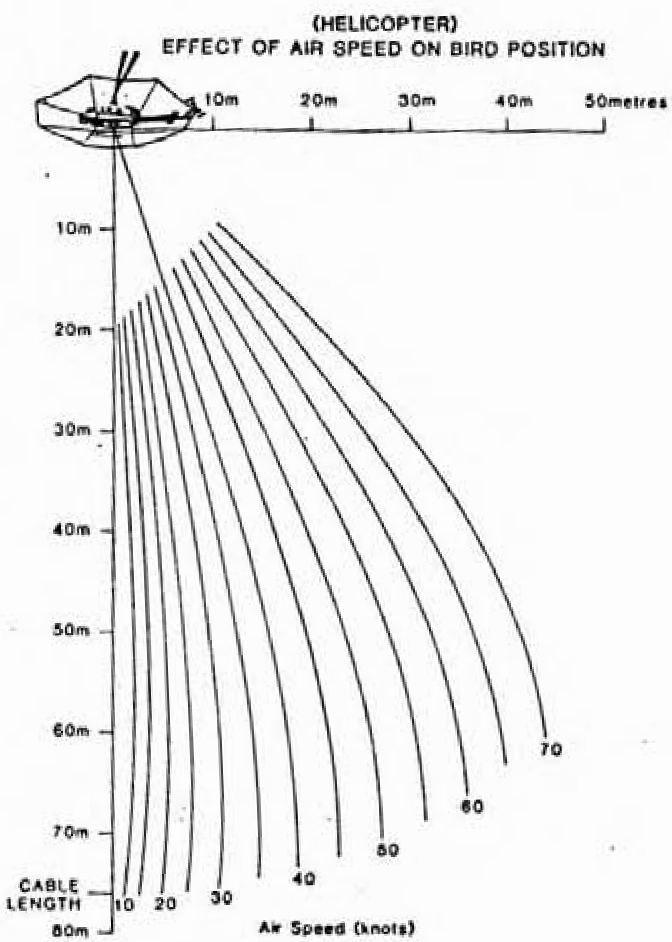


Figure C1

b) The Lag Factor

The bird's spatial position along with the time constant of the system introduces a lag factor (Figure C2) or shift of the response past the actual conductor axis in the direction of the flight line. This is due to fiducial markers being generated and imprinted on the film in real time and then merged with E.M. data which has been delayed due to the two aforementioned parameters. This lag factor necessitates that the receiver response be normalized back to the helicopter's position for the map compilation process. The lag factor can be calculated by considering it in terms of time, plus the elapsed distance of the proposed shift and is given by:us the elapsed distance of the proposed shift and is given by:

$$\text{Lag (seconds)} = \text{time constant} + \frac{\text{bird lag (metres)}}{\text{ground speed (metres/sec)}}$$

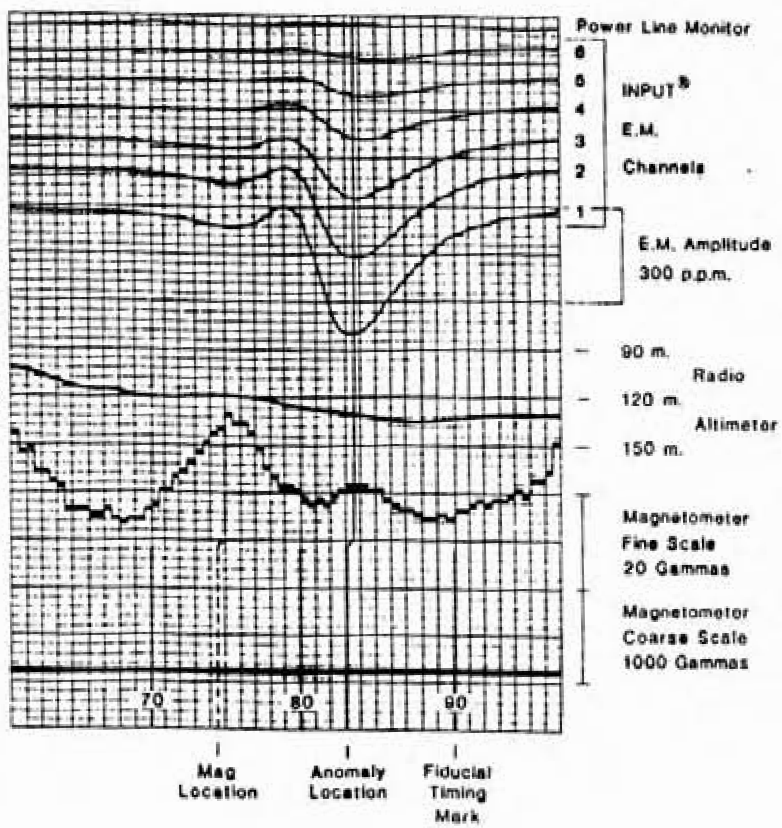


Figure C2

The time constant introduces a 1.3 second lag while, at an aircraft velocity of 40 kt., the 'bird' lag is 1 second. The total lag factor which is to be applied to the INPUT E.M. data at 40 kts. is 2.3 seconds. It must be noted that these two parameters vary within a small range dependent on the helicopter velocity, though they are applied as constants for consistency. As such, the removal of this lag factor will not necessarily position the anomalies in a straight line over the real conductor axis. The offset of a conductor response peak is a function ot the system and conductor geometry as well as conductivity.

The magnetic data has a 1.0 second lag factor introduced relative to the real time fiducial positions. This factor is software controlled with the magnetic value recorded relative to the leading edge (left end) of each step 'bar', for both the fine and coarse scales. For example, a magnetic value positioned at fiducial 10.00 on the records would be shifted to fiducial 9.95 along the flight path.

A lag factor of 2 seconds (0.1 fiducial) is introduced to correct 50-60 Hz monitor for the effects of bird position and signal processing. In cases where a 50-60 Hz signal is induced in along formational conductor, a 50-60 Hz secondary electromagnetic transient may be detected as much as 5 km. from the direct source over the conductive horizon.

The altimeter data has no lag introduced as it is recorded in real time relative to the fiducial markings.

c) Calibration

The major advance made during the transition from the INPUT MK V to the INPUT MK VI has been the ability to calibrate the equipment accurately and consistently. Field tests at established test sites are carried out on an average of once every 6 months to check the consistency of the INPUT installations available from QUESTOR.

To calibrate the equipment for a survey operation the following tests are used:

1) "ZERO" the digital and record background E.M. levels;
2) magnetometer scale calibrations;
3) altimeter calibration;
4) calibration of INPUT receiver gain;
5) aircraft compensation;
6) record background E.M. levels at 600 m.;
7) survey flight;
8) record background E.M. levels at 600 m.
9) record full scale INPUT receiver gain;
10) record compensation drift;
11) terminate or repeat from step 4.

This sequence of tests may be repeated in midflight given that the duration of the flight is sufficiently long. Typically, this process is conducted every 2 hours of actual flying time and at the termination of every flight.

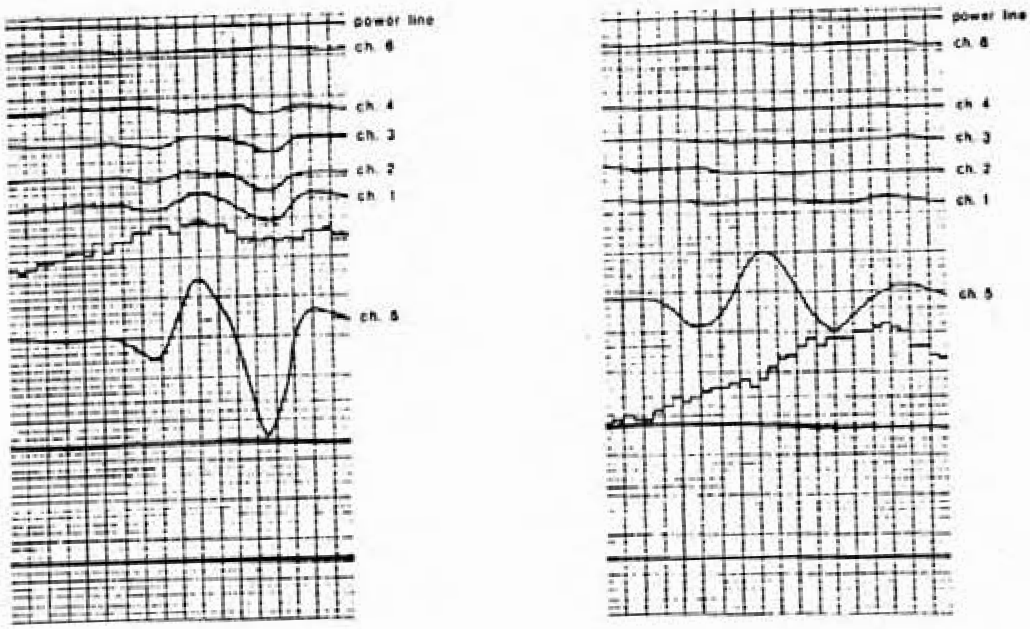
The background levels are recorded and then used to determine the drift that may occur in the E.M. channels during the progression of a survey flight. If drift has occurred, the

E.M. channels are brought back to a levelled position by use of the linear interpolation technique during the data processing.

The primary electromagnetic field generated by the INPUT system induces eddy currents in the frame of the helicopter. This spurious secondary field is a significant source of noise which needs to be taken account of before every survey flight is initiated.

Compensation is the technique by which the effects of this spurious secondary field are eliminated. A reference signal, which is equal in amplitude and waveform but opposite in polarity, is obtained from the primary field voltage in the receiver coil and applied to each channel of the receiver. The compensation signal is not a constant value due to coupling differences induced by 'bird' motion relative to the aircraft. The signal applied is proportional to the inverse cube of the distance between the 'bird' and aircraft. Figure C3 displays the effect of compensation.

Typically, channel 5 is selected for compensation because it is not affected by geological noise due to its sampling location in the transient and then coupling changes are induced by precipitating 'bird' motion. Phase considerations of channel 5, relative to the remaining channels, dictates whether sufficient compensation has been applied. If the remaining channels are in-phase to channel 5 during this procedure, an over-compensated situation is indicated, whereas, out-of-phase would be indicative of an under-compensation case. Normally this adjustment is carried out at an altitude of 600 metres in order to eliminate the influence of external geological and cultural conductors.



Uncompensated

Compensated

Figure C3

The magnetometer, altimeter and INPUT receiver gain are also calibrated at the initiation of every survey flight. With the magnetometer, there are two scales, a coarse and a fine scale. The fine scale indicates a 10 gamma change for a 1 cm. change in amplitude (Figure C2). The coarse scale moves 2 mm. (or 1 division) for a 100 gamma change with full scale,2 cm., indicating a 1000 gamma shift.

The altimeter (Figure C4), is calibrated to indicate 400 feet altitude at the seventh major division (7 cm.), read from the bottom of the analog record. This is the nominal flying height of INPUT surveys, wherever relief and aircraft performance are not limiting factors. The eighth major division correlates with 300 feet while the sixth corresponds with 500 feet in altitude.

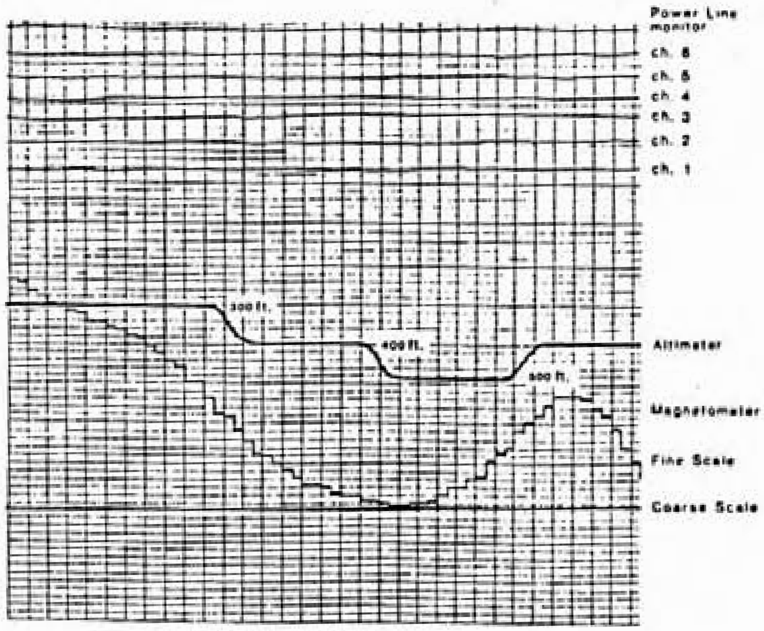


Figure C4

The INPUT receiver gain is expressed in parts per million of the primary field amplitude at the receiver coil. At the 'bird', the primary field strength is 8.5 and 8 volts peak-to-peak, for the vertical and horizontal axis coils respectively or 4.2 and 4.0 volts peak amplitude. The calibration signal introduced at the input stage of the receiver is 4.0 mV. Expressed in parts- per-million, this induces a change of:

$$\frac{4 \times 10^{-3} \times 10^{6}}{4.2} = 1{,}000 \text{ ppm (vertical coil)}$$

These calibration signals (Figure C5) cause an 8 cm. deflection of all 6 traces which translates to a sensitivity of 125 ppm/cm. for the vertical axis receiver coil system.

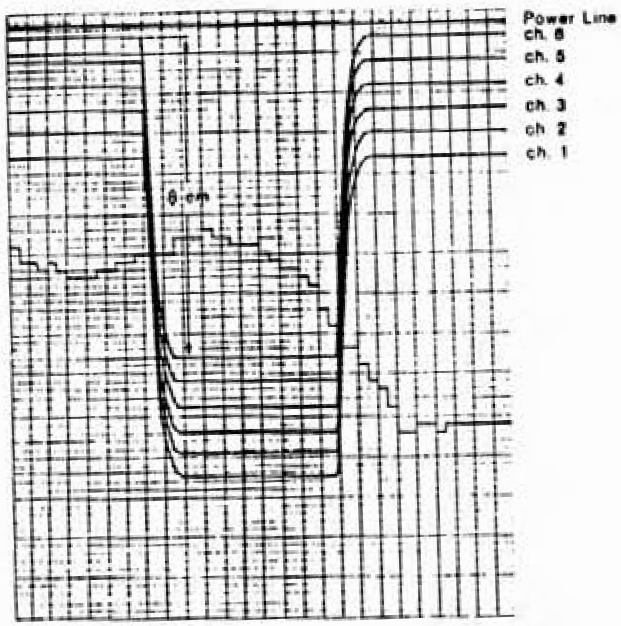


Figure C5

With the chart speed increased from the normal 0.25 cm. to 2.5 cm. per second, the time constant of the system (Figure C6), can be obtained by analysis of the exponential rise of the calibration signal for all 6 traces. The time constant, is defined as the time for the calibrated voltage to build up or decay to 63.2% of its final of initial value. A longer time constant reduces background noise but also has the effect of reducing the amplitude of the signal, especially for near surface responses.

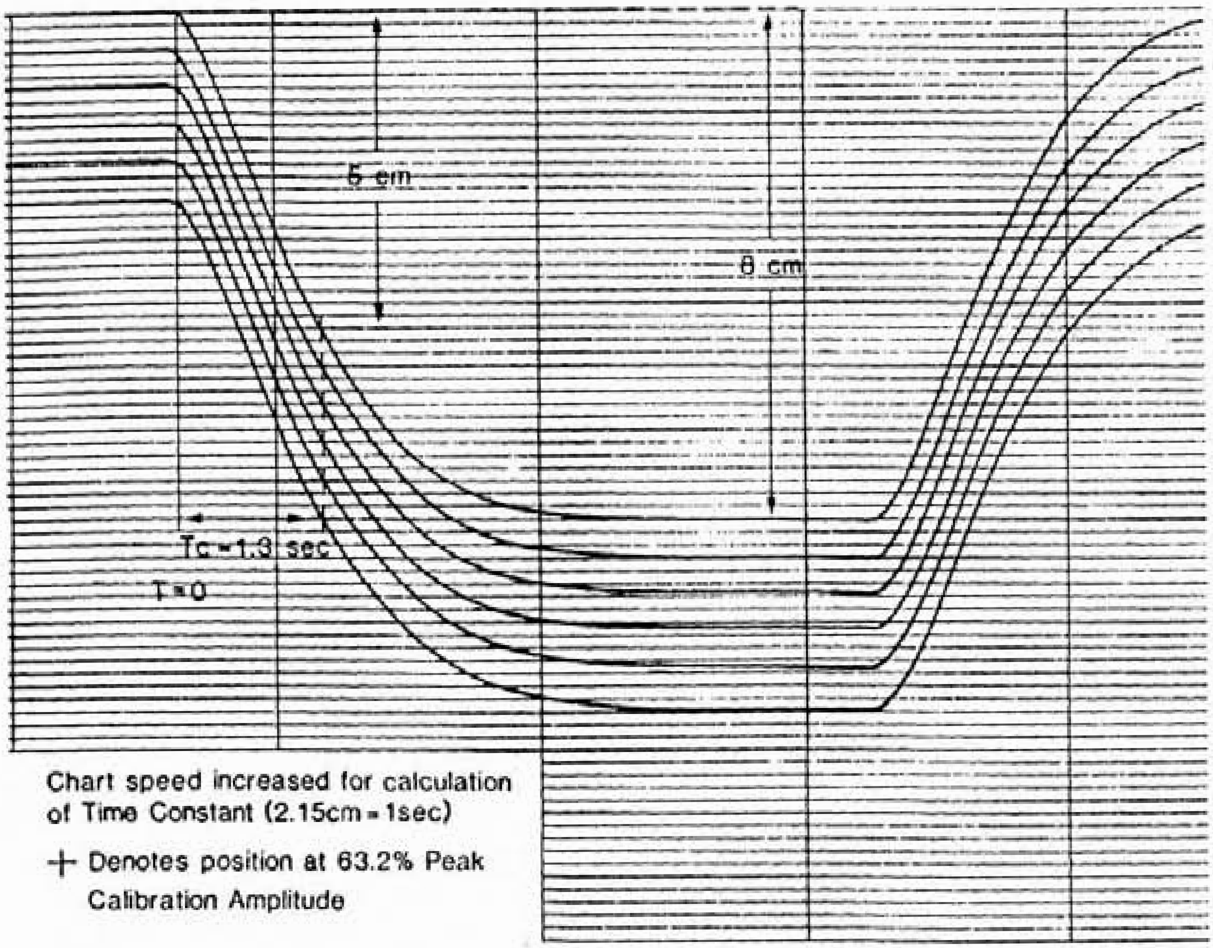


Figure C6

This trade-off indicates the importance of selecting an optimum value for the time constant. Experience and years of testing have indicated that a time constant of 1.3 second does not impede interpretation of bedrock source conductors.

d) Depth Penetration Capabilities

There are many factors which effect the depth of penetration. These factors consist of:

1) altitude of the helicopter above the ground;
2) conductivity contrast between conductor and host rock;
3) size and attitude of conductor;
4) type and conductivity of overburden present.

Of these factors, only the first parameter can be controlled. Typically, a survey altitude of 120 metres (400 feet) or less above the terrain is maintained. At this height, the helicopter INPUT MARK VI system has responded to conductors located at a depth of 200 metres (650 feet) below the surface.

APPENDIX D

INPUT Data Processing

The QUESTOR designed and implemented computer software routines for automatic interactive compilation and presentation, may be applied to all QUESTOR INPUT Systems. The software is compatible with the fixed-wing MARK VI INPUT, and the helicopter MARK VI INPUT. The procedures are all common, however, separate subroutines are accessed which contain the unique parameters to each system. Although many of the routines are standard data manipulations such as error detection, editing and levelling, several innovative routines are also optionally available for the reduction of INPUT data. The flow chart on the following page (Figure D1) illustrates some of the possibilities. Software and procedures are constantly under review to take advantage of new developments and to solve interpretational problems.

a) INPUT Data Entry and Verification

During the data entry stage, the digital data range is compared to the analog records and film. The raw data may be viewed on a high-resolution video graphics screen at any desirable scale. This technique is especially helpful in the identification of background level drift and instrument problems.

b) Levelling Electromagnetic Data

Instrument drift, recognized by viewing compressed data from several hours of survey flying, is corrected by an interactive levelling program. Although only two or three calibration sequences are normally recorded, the QUESTOR technique permits the use of multiple non-anomalous background recordings to divide a possible problematic situation into segments. All 6 INPUT channels are levelled simultaneously, yet independently. The sensitivity of the levelling process is normally better than 10 ppm on data with a peak-to-peak noise level of 30 ppm.

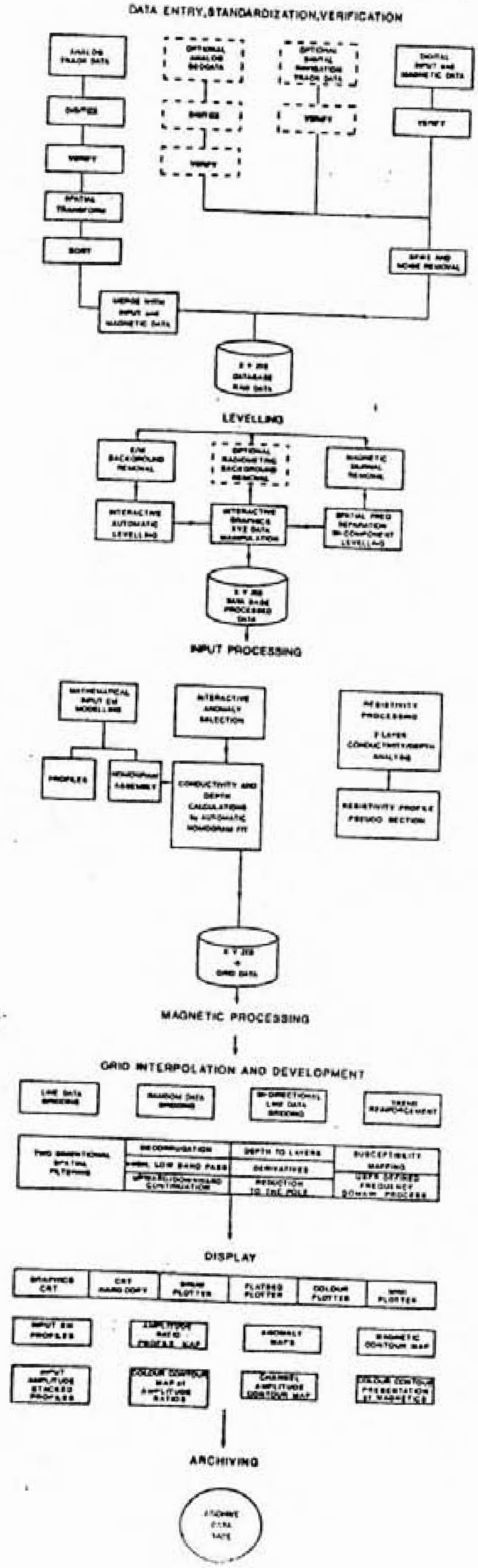
c) Data Enhancement

Normal INPUT processing does not include the filtering of electromagnetic data. The residual high frequency variations often apparent on analog INPUT data, is due almost wholly to "spherics", atmospheric static discharges. In conductive environments, spherics are apparently grounded and effectively filtered. In resistive environments, frequency spectrum analysis and subsequent FFT (Fast Fourier Transform) filters have been applied to data to reduce the noise envelope.

d) Selection of EM Anomalies

The levelled data may be viewed sequentially on a graphics screen for the selection of INPUT anomalies. Anomalies are selected by aligning a cursor to the position of the peaks. Some of the parameters of the response are manually entered during the picking of the response. These include the number of channels above background levels and the type of anomaly, e.g. cultural, bedrock, surficial, up-dip, etc.

QUESTOR INPUT DATA PROCESSING



APPENDIX E

INPUT INTERPRETATION PROCEDURES

The INPUT system is dependent upon a definite resistivity contrast and is most suitable for highly conductive massive sulphides. Differentiation is possible between flat-lying surficial conductors and bedrock conductors.

The selection of anomalies is based on their characteristics and interpretation is sometimes enhanced by analyzing the magnetics. Spherics, due to atmospheric static discharges and lightning storms, are distinguishable from conductive anomalies. In the analysis of each conductor anomaly, the following parameters may be considered: anomaly shape with the conductor pattern, topography, corresponding magnetic features, anomaly decay rate, the number of channels affected, geological environment and strike direction and the interpreted dip relative to structural features.

For each anomaly selected, the following are recorded: location by fiducial, channel amplitudes in parts per million, number of channels, conductivity-thickness in siemens, corresponding magnetic association in gammas, magnetic fiducial location altitude of aircraft above ground in metres and also, the origin of the response (ie. surficial, bedrock, cultural).

Conductive responses are categorized into three main groups. These are bedrock, surficial and cultural.

Bedrock conductors can be sorted into conductive sources which are commonly encountered on INPUT surveys: massive sulphides, graphites, serpentinized peridotites and fault or shear zones. Magnetite and manganese concentrations may also yield INPUT responses in some circumstances. INPUT responses over alkalic intrusives and weathered basic volcanics have been well documented by Macnae (1979) and Palacky (1979).

Massive Sulphides

Massive sulphides occur as both syngenetic and stratified deposits and as vein infilling deposits. Nickel deposits often occur as magmatic injections of massive sulphides. Kuroko-type syngenetic copper-zinc massive sulphides usually occur at an interface of felsic intermediate rocks. In this environment, there are seldom any significant formations of carbonaceous sediments on the same horizon. Often, these deposits are overlain by a silicious zone which may contain stingers of continuous sulphides, which change to disseminated sulphides away from the main deposit. These often give a deposit the appearance of a long strike-length zone which may not fit the explorationist's target model. A careful analysis of conductivities and apparent widths (half-peak-width), will often reveal the geometry and source. Syngenetic deposits of base metal sulphides of up to 2 km strike length are not unknown, although most sizeable deposits have strike lengths between 500 and 1000 m.

The conductivity of most massive sulphide deposits may be attributed to the pyrrhotite and chalcopyrite content, as both minerals form elongated interconnected masses which are most amenable to the induction of electromagnetic secondary fields. Pyrite normally forms cubic crystals which must be interconnected electrically in order to produce a response. Massive pyrite often produces only a moderate response which may be difficult to distinguish from graphite. The in-situ conductivity of massive sulphides, although very high for individual crystals, often falls in the range of 5 to 20 S/m.

Sulphide conductive zones are rare in nature; economic sulphides are even more scarce. Long formational sulphide zones are known, but are not common. More often, sulphide concentrations may occur within formational graphitic zones.

The geometry of many syngenetic and injected sulphide deposits may fall within broad classifications of size, conductivity and magnetization but most of these bodies are anomalous within their local geological environment. There are often changes in dip, conductivity, thickness and magnetization with respect to the regional environment. There are no rules which apply universally to massive sulphide deposits. One observation which has consistently applied to sulphide deposits is that INPUT responses (amplitude and conductivity) are roughly proportional to mineral content.

The INPUT system is capable of detecting disseminated sulphides within zones of resistivity changes. These may have low conductivities and responses will normally be restricted to channels 1 through 4. The response amplitudes will vary with the horizontal and vertical extent of the zone. Gold deposits often fall within this response classification.

The magnetic response of a sulphide deposit is the most deceiving information available to the explorationist. Although many large economic deposits have a strong direct magnetic association, some of the largest base metal deposits have no magnetic association. An isolated magnetic anomaly caused by oxidation conditions at a volcanic vent flanking a conductor, may have more significance than a body which has a uniform magnetic anomaly along its strike length. Differing geochemical environments often results in the zoning of minerals so that non-homogeneous conductivities and magnetic responses may be favourable parameters.

Graphitic Carbonaceous Conductors

Carbonaceous sediments are usually found within the sedimentary facies of Precambrian and Proterozoic greenstone belts. These represent a low energy, sedimentary environment with good bedding planes and little or no structural deformation. Graphites are often located in basins of the sub-aqueous environment, producing the same body shape as sulphide concentrations. Most often however, they form long, homogeneous planar sequences. These may have thicknesses from a metre to hundreds of metres. The recognition of graphites in this setting is normally straightforward.

Conductivities and apparent widths may be very consistent along strike. Strike lengths of tens of kilometres are common for individual horizons.

The conductivity of a graphite unit is a function of two variables:

a) the quality and quantity of the graphite and

b) the presence of pyrrhotite as an accessory conductive mineral

Pyrite is the most common sulphide mineral which occurs within carbonaceous beds. It does not contribute significantly to the overall conductivity as it will normally be found as disseminated crystals. Greenschist facies metamorphosis will often be sufficient to convert carbonaceous sediments to graphitic beds. Likewise, pyrite will often be transformed to pyrrhotite.

Without pyrrhotite, most graphitic conductors have less than 20 S conductivity-thickness value as detected by the INPUT system or 1 to 10 S/m conductivity from ground geophysical measurements. With pyrrhotite content, there may be little difference from sulphide conductors.

It is not unusual to find local concentrations of sulphides within graphitic sediments. These may be recognized by local increases in apparent width, conductivity or as a conductor offset from the main linear trends.

Graphite has also been noted in fault and shear zones which may cross geological formations at oblique angles.

Serpentinized Peridotites

Serpentinized peridotites are very distinguishable from other anomalies. Their conductivity is low and is caused partially by magnetite. They have a fast decay rates, large amplitudes and strong magnetic correlation.

Magnetite

INPUT anomalies over massive magnetites correlate to the total Fe content. Below 25-30% Fe, little or no response is obtained. However, as the Fe percentage increses, strong anomalies result with a distinguished rate of decay that usually is more pronounced than those for massive sulphides.

Contact zones are often predicted when anomaly trends coincide with lines of maximum gradient along a flanking magnetic anomaly.

Surficial Conductors

Surficial conductors are characterized by fast decay rates and usually have a conductivity-thickness of 1-5 siemens. These values will be much higher in saline conditions. Overburden responses are broad, more so than bedrock conductors. Anomalies due to surficial conductivity are not dependent on flight direction. In profile form, surficial responses are symmetrical from line-to-line with the Helicopter INPUT system, and are characterized by a single response rather than a double peak for dipping and vertical conductors. Conductive deposits such as clay beds, may lie in valleys which can be checked on the altimeter trace and with the base maps topography.

Cultural Conductors

Cultural conductors are identifiable by examining the power line monitor and the film to locate railway tracks, power lines, buidings, fences or pipe lines. Power lines produce INPUT anomalies of high conductivity that are similar to bedrock responses. The strength of cultural anomalies is dependent on the grounding of the source. INPUT anomalies usually lag the power line monitor by 1 second, which should be consistent from line-to-line. If this distance between the INPUT response and the power line monitor differs between lines, then there is the possibility of an additional conductor present. The amplitude and conductivity-thickness of anomalies should be relatively consistent from line-to-line.

ANOMALY	FID	NO. OF CHS.	CH. 1 AMPLITUDE	CH.2 AMPLITUDE	CONDUC-TIVITY	MAG	VALUE
10100A	44.80	1	75	-	-	-	-
10100B	45.80	3	180	50	4	45.70	8
10100C	46.30	5	510	190	7	-	-
10100D	46.90	5	615	270	15	47.10	8
10100E	47.63	5	830	440	15	-	-
10200A	49.50	6	570	360	40	-	-
10300A	51.39	5	390	300	55	-	-
10300B	52.05	6	600	480	25	52.10	55
10300C	52.60	4	300	75	15	-	-
10300D	53.33	1	240	-	-	52.85	30
10400A	54.30	3	180	90	9	54.10	32
10400B	54.80	6	450	240	17	-	-
10400C	55.30	6	750	490	33	35.25	10
10500A	56.00	6	640	430	40	-	-
10500B	56.52	6	590	380	30	-	-
10500C	57.18	5	300	170	20	57.00	18
10500D	57.50	5	250	140	20	-	-
12310A	27.82	4	120	70	10	-	-
12310B	28.18	6	410	360	20	-	-
12310C	28.80	3	60	25	6	28.75	30
12320A	37.70	3	30	20	15	37.45	44
12320B	38.60	5	140	90	22	-	-
12320C	38.90	4	130	80	25	38.80	33
12320D	39.60	3	90	50	13	-	-
60351A	21.90	1	30	-	-	21.55	42
60352A	14.85	1	30	-	-	14.35	50
60352B	15.50	1	45	-	-	-	-

Recovered Fiducials

Line No.	Fiducial No.
10100W	429
	435
	445
	452
	460
	468
	478
	485
10200E	486
	491
	495
	502
	506
10300W	507
	512
	519
	522
10400E	536
	542
	546
	550
	559
10500W	560
	565
	576
	583

Line No.	Fiducial No.
03520E	126
	143
	159
	164
	172
	178
	188
03510W	194
	208
	219
	231
	242
	253
	261
	265
12310E	269
	276
	280
	295
	303
	309
	320
	330
	332

Line No.	Fiducial No.
12320W	338
	344
	350
	357
	363
	368
	383
	388
	396
	406
	413

INPUT* – Helicopter Vertical Axis Coil

SURFICIAL RESPONSE	UP-DIP PEAK RESPONSE	BEDROCK RESPONSE	DECAY INTERVAL CLASSIFICATION
			1 Channel (300 microseconds)
			2 Channel (500 microseconds)
			3 Channel (800 microseconds)
			4 Channel (1200 microseconds)
			5 Channel (1700 microseconds)
			6 Channel (2300 microseconds)

Culture Response

50 Associated Magnetic Response

Anomaly Letter — B 5 — Apparent Conductivity Width (siemens) (N.C. – No Calculation)

Poorly Defined Response — 1800 — Ch. 2 Amplitude (p.p.m.)

INTERPRETATION

20 Conductor Axis, with reference number (good definition)

20 Conductor Axis, with reference number (poor definition)

Vertical Conductor

60° Conductor Dip (magnitude and direction known)

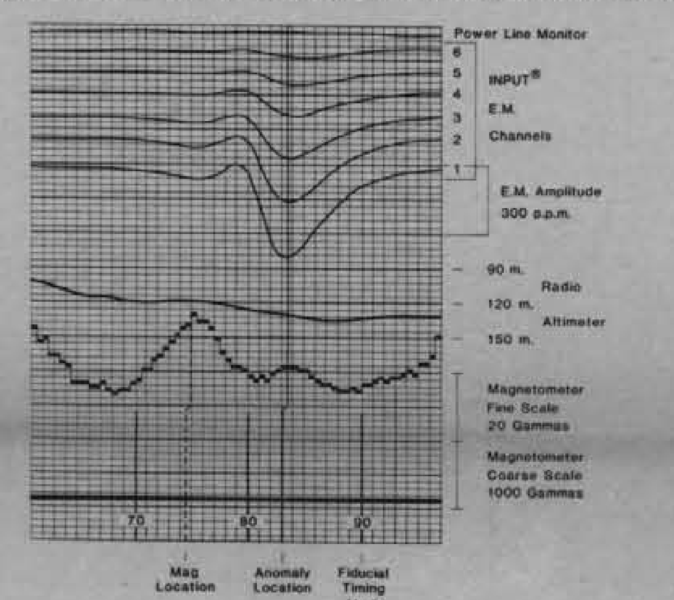
Conductor Dip (direction known)

20 Selected Zone, with reference number

Conductive Zone

Fault Zone

Representative INPUT* Magnetometer and Altimeter Recording



DESCRIPTIVE NOTES

The aircraft is equipped with the Barringer/Questor Mark VI INPUT* airborne E.M. System and the Sonotek PMH 5010 Proton Precession Magnetometer and Sonotek SDS-1200 Series Data Acquisition System. The INPUT* system will respond to conductive overburden and near-surface horizontal conducting layers in addition to bedrock conductors. Discrimination of conductors is based on the rate of transient decay, magnetic correlation and the anomaly shape, together with the cunductor pattern and topography.

* Registered Trade Mark of Barringer Research Limited

INTERPRETATION REFERENCES

Becker, A., Gauvreau, C., and Collett, L.S.
1972 Scale Model Study of Time Domain Electromagnetic Response of Tabular Conductors; Canadian Mining and Metallurgical Bulletin, Volume 65, No. 725, p. 90-96.

Dyck, A.V., Becker, A., and Collett, L.S.
1974 Surficial Conductivity Mapping with the Airborne INPUT* System; Canadian Mining and Metallurgical Bulletin, Volume 67, No. 744, p. 104-109.

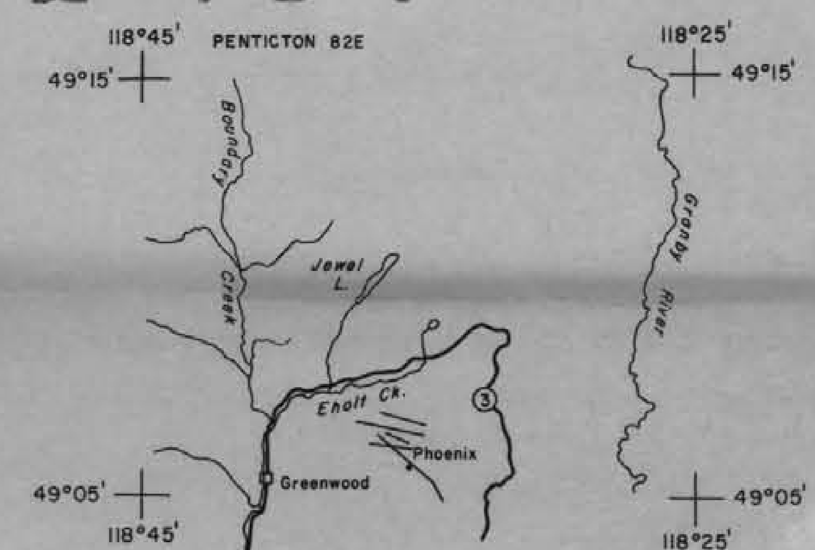
Lazenby, P.G.
1973 New Developments in the INPUT* Airborne E.M. System, Canadian Mining and Metallurgical Bulletin, Volume 66, No. 732, p. 96-104.

[illegible]
Model Re[illegible] for Time-Domain Airborne E.M. System; Geophysics, Volume [illegible], No. 5, p. 845-853.

GEOLOGICAL BRANCH
ASSESSMENT REPORT

11,845

part 1 of 2



Scale Approx. 1:10 000 0 100 m

HELICOPTER MK VI INPUT® SURVEY
(Vertical Coil)

KETTLE RIVER RESOURCES LTD.

SYLVESTER K – PHOENIX AREA

Province of BRITISH COLUMBIA

FILE NO.	SHEET NO.	DATE	COMPILED BY.
25H52	1 of 1	Oct.,1983	Questor Surveys Ltd.

Questor Surveys Limited
Mississauga, Ontario Canada

INPUT* – Helicopter Vertical Axis Coil

SURFICIAL RESPONSE	UP-DIP PEAK RESPONSE	BEDROCK RESPONSE	DECAY INTERVAL CLASSIFICATION
			1 Channel (300 microseconds)
			2 Channel (500 microseconds)
			3 Channel (800 microseconds)
			4 Channel (1200 microseconds)
			5 Channel (1700 microseconds)
			6 Channel (2300 microseconds)

Culture Response

50 Associated Magnetic Response

Anomaly Letter – B
Apparent Conductivity Width (siemens) (N.C. – No Calculation) – 5
Poorly Defined Response – *
Ch. 2 Amplitude (p.p.m.) – 1800

INTERPRETATION

20 Conductor Axis, with reference number (good definition)

20 Conductor Axis, with reference number (poor definition)

Vertical Conductor

60° Conductor Dip (magnitude and direction known)

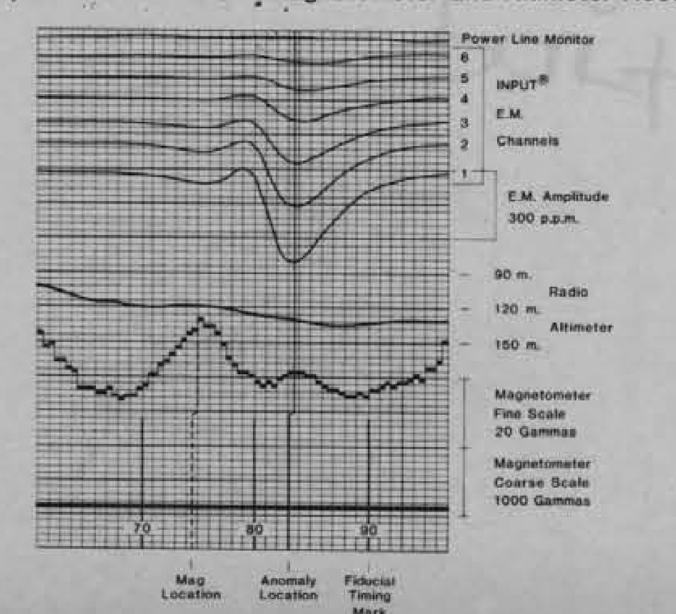
Conductor Dip (direction known)

20 Selected Zone, with reference number

Conductive Zone

Fault Zone

Representative INPUT* Magnetometer and Altimeter Recording



DESCRIPTIVE NOTES

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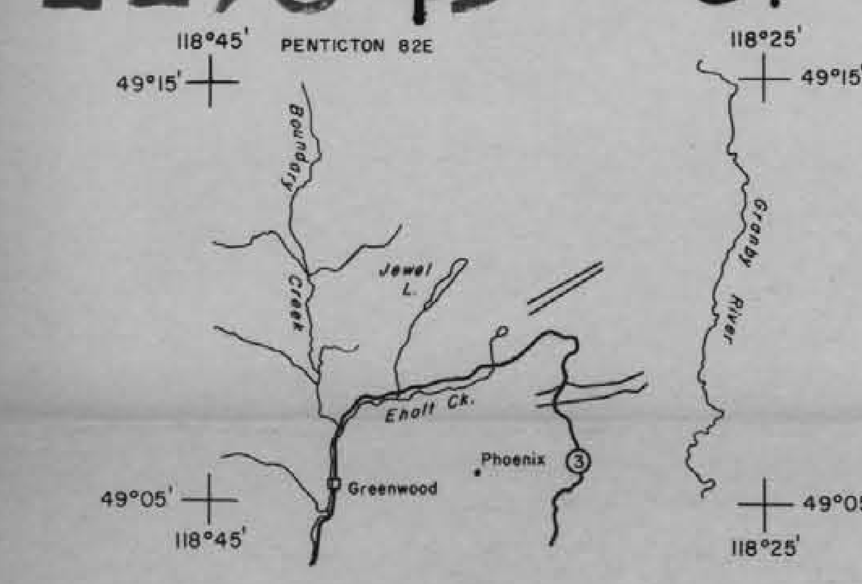
1973: New Developments in the INPUT* Airborne E.M. System; Canadian Mining and Metallurgical Bulletin, Volume 66, No. 732, p. 96-104.

Nelson, Philip H.
1973: Model Results and Field Checks for a Time-Domain Airborne E.M. System; Geophysics, Volume 38, No. 5, p. 845-853.

GEOLOGICAL BRANCH
ASSESSMENT REPORT

11,845

Part 1 of 2



Scale Approx. 1:10 000 0 100 m

HELICOPTER MK VI INPUT® SURVEY
(Vertical Coil)

KETTLE RIVER RESOURCES LTD.

YOUNG GEORGE PROJECT

Province of BRITISH COLUMBIA

FILE NO.	SHEET NO.	DATE	COMPILED BY.
25H52	1 of 1	Oct.,1983	Questor Surveys Ltd.

Questor Surveys Limited
Mississauga, Ontario Canada