TECHNICAL REPORT ON A FIXED WING AEROMAGNETIC SURVEY

CENTRAL ROCKIES, COLORADO

SOLICITATION NUMBER
02CRQQ0153

for

UNITED STATES GEOLOGICAL SURVEY

by

GOLDAK AIRBORNE SURVEYS

October/November, 2002

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1. INTRODUCTION

This report describes an airborne geophysical survey carried out in the Central Rockies region of Colorado on behalf of the United States Geological Survey (USGS). The airborne total field magnetic survey was carried out over Lake County County. The survey block was approximately centered on the community of Leadville. The survey took place between November 30 and December 10, 2002.

Aircraft equipment operated included three cesium vapor, digitally compensated magnetometers, a dual-frequency GPS real-time and post-corrected differential positioning system, a flight path recovery camera, a VHS video titling and recording system, as well as dual radar and barometric altimeters. All data was recorded digitally in GEDAS binary file format.

Reference ground equipment included a Geometrics G823A cesium vapor magnetometer, a GEM Systems Overhauser Proton magnetometer and a Novatel 12 channel dual-frequency GPS base station.

The community of Leadville is at the approximate center of the survey block, some 150 kilometers southwest of the city of Denver.

The initial flight for equipment calibration and test was made on November 28. Eighteen survey flights were required to complete the data acquisition phase of the project. The survey flights took place between November 28th and December 10th.

The flight lines for were oriented on an azimuth of 090°/270°T (true with respect to UTM North) with control lines at 000°/180°T. 11636 line kilometers of data was acquired and 11448 km accepted.

The survey was flown with a traverse line separation of 400 meters and a control line spacing of 3200 meters. Aircraft height was specified at 400 meters above ground.

2. SURVEY AREA LOCATION

The Central Rockies survey area is located approximately 150 kilometers southwest of Denver, Colorado and is centered at N 39° 12'   W 106° 12'.

The location of the survey area is indicated by the dark shading on the map of Colorado shown below.

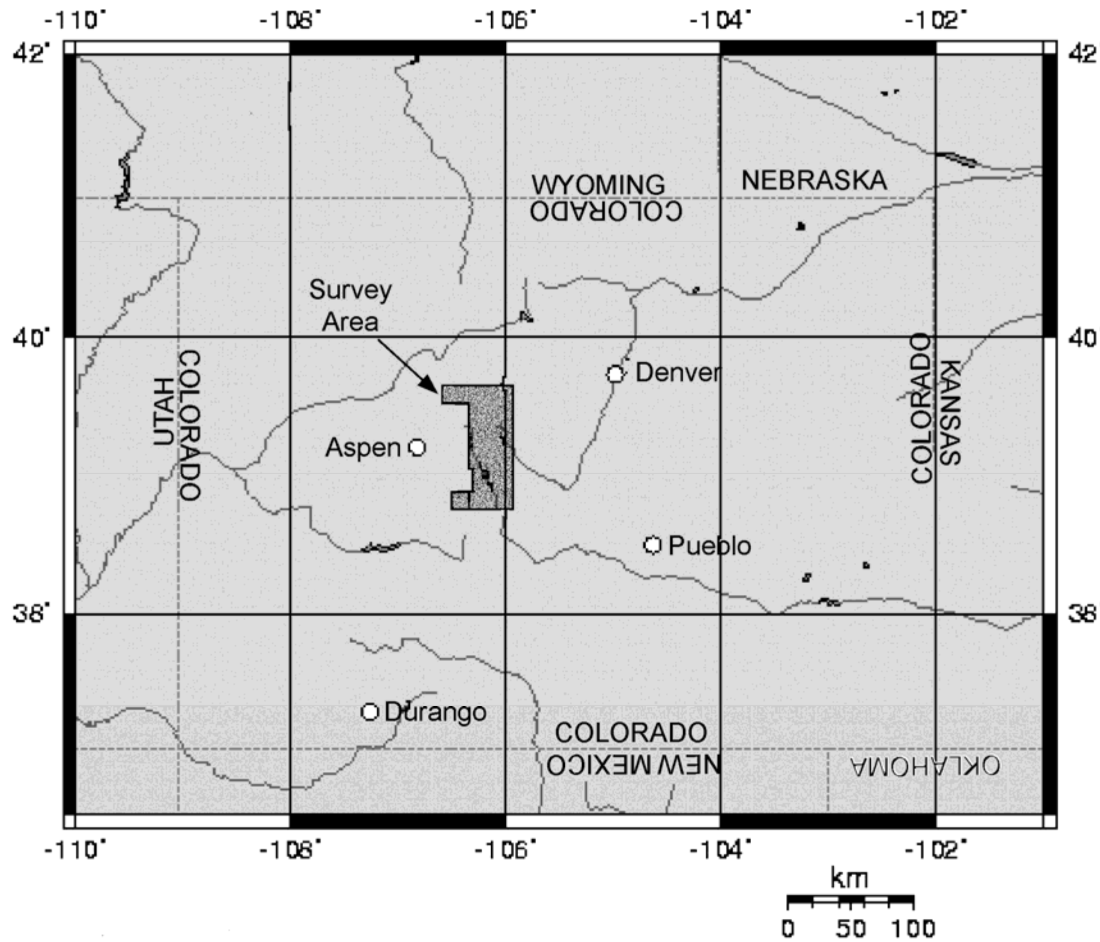


Illustration – Survey Location Map

Accommodations were made, and the field office setup at the Best Western Inn, 733 Hwy 24 North Buena Vista, CO.

Illustration – Field Office Location

The survey block was defined by the following NAD-27 geographic coordinates:

38°45’00”	-106°30’00”
38°52’30”	-106°30’00”
38°52’30”	-106°20’00”
39°00’00”	-106°20’00”
39°00’00”	-106°22’30”
39°30’00”	-106°22’30”
39°34’00”	-106°25’00”
39°34’00”	-106°32’30”
39°40’00”	-106°32’30”
39°40’00”	-105°58’00”
38°45’00”	-105°58’00”

The coordinates were projected for field use to the following WGS-84 UTM Z10N pairs.

369600.18	4290103.15
369827.85	4303974.91
384286.56	4303750.49
384489.47	4317622.32
380881.16	4317675.99
381723.88	4373166.36
378257.58	4380620.98
367519.46	4380797.60
367709.93	4391896.49
417033.37	4391207.21
415948.32	4289478.57

The flight lines were oriented on an azimuth of 090°/270° with respect to UTM north. Orthogonal control lines on an azimuth of 000°/180° degrees were used.

A traverse line separation of 400 meters and a tie line separation of 3200 meters were used.

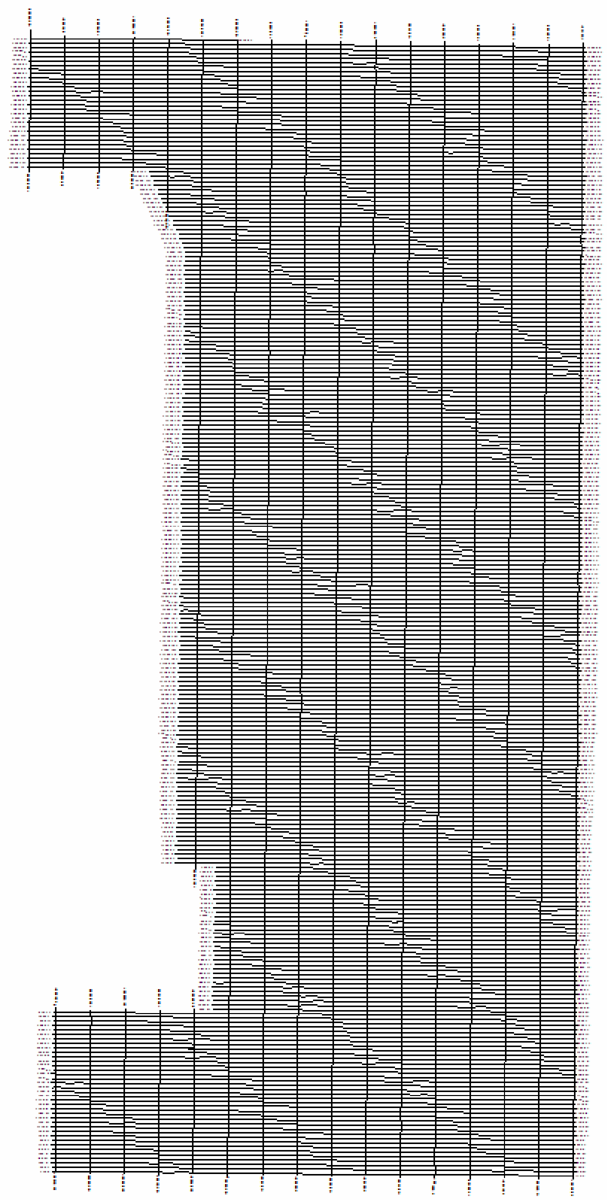


Illustration – Ideal Flight Path

The lines were flown at a nominal terrain clearance of 400 meters (1300 feet). The vertical navigation was accomplished using a pre-planned drape altitude surface.
This surface was developed using USGS digital elevation data (DEM) obtained from GIS Data Depot.

3. DATA SPECIFICATION

The nominal traverse line separation was 400 meters, with a control line spacing of 3200 meters. The standard tolerance for horizontal line navigation was ± 10% of the flight line spacing with a gap between adjacent lines of 150% nominal spacing for a length of 3.2 km requiring a reflight.

Altitude control was accomplished by GEDAS auto-drape system using a pre-defined altitude drape surface. The surface was developed using USGS DEM data. The specified terrain clearance altitude was 230 meters with a tolerance of ± 61 meters from an ideal drape surface over a 1000-meter distance, with the usual exceptions made for rugged terrain, regulatory compliance or aircraft safety considerations

Diurnal activity tolerance was specified as maximum 5nT for any five-minute period. Pulsations were limited to the following parameters: 2nT deviation from a straight-line chord whose length is 300 seconds in length; 4 nT for 300 to 600 seconds and 8 nT for 600 to 1200 seconds.

The flight data magnetic noise tolerance was specified as not to exceed ± 0.1 nT over a maximum distance of 1000 meters.

The aircraft maneuver noise was specified as a Figure of Merit of less than 2.0 nT. The FOM was flown with ±5° pitches, ±10° rolls and ±5° yaws on four cardinal headings. The FOM is then the arithmetic sum of the mean peak-to-peak response for all 12 maneuvers.

Further, the maximum magnetic response due to as single roll or pitch maneuver of ± 20 degrees is specified as 3nT. The maximum allowed heading error is 1nT. The initial tests performed easily meet these specifications.

4. AIRCRAFT AND EQUIPMENT

4.1 Aircraft

The aircraft used was a Piper PA-31 Navajo, registration C-GJBB, owned and operated by Goldak Exploration. The aircraft is fitted with a 3-meter stinger attached to the rear fuselage on the centerline of the aircraft. The attitude sensing fluxgate magnetometer is positioned at the midpoint of the stinger. The aircraft also has magnetometers installed in composite pods on each wingtip. The pods mount the sensors 1.2 meters outboard of the aircraft wingtip. The three magnetometers form a two-axis gradiometer with following dimensions:

Lateral	14.83m
Longitudinal	8.66m

The aircraft has been extensively modified, both mechanically and electrically to minimize the effects of maneuvering on the measured magnetic field. The aircraft has a demonstrated Figure of Merit of less than 0.7 nT as measured to GSC (Geological Survey of Canada) specification. Typical FOMs under less than ideal calibration environments are 0.9 nT for the tail magnetometers. This low level of magnetic noise is considered to be exceptional by experts at the National Research Council.

Illustration - PA-31 Navajo C-GJBB in Horizontal Gradient Survey Configuration

4.2 Magnetometer and Compensation

The airborne magnetometers used are a matched set of Geometrics G-822A optically pumped cesium vapor types with sensitivity of 0.005 nT. The magnetometer's Larmor signal is decoupled and counted by a RMS Instruments AADCII compensator, and data produced at a rate of either 10 Hz with a resolution of 0.001 nT. The data bandwidth is from 0 to 0.9 Hz with an internal noise level of less than 0.002 nT.

The AADCII compensates for magnetic noise due to aircraft motion and heading. Prior to the survey, the aircraft is taken to an area of low magnetic gradient at a high altitude (7000' AGL +) and put through a series of rolls, pitches and yaws on each of the survey's cardinal headings. This is done so that the AADCII can form a model of the aircraft's magnetic characteristics without the near influence of the local geology. The remaining magnetic distortion is quantified by a term known as the Figure of Merit, or FOM. A figure of merit of 2.0 or less is used by the Geological Survey of Canada as standard survey criteria. As stated above, this aircraft has an exceptional typical FOM of approximately 0.9 nT.

The following table represents the digital analysis of the initial compensation and FOM data taken prior to this survey in the vicinity of the survey area within an area of low magnetic gradient. The flight was made on November 28, 2002. The results are typical and are indicative of a good compensation fit to the aircraft maneuver noise.

RMS AADCII Compensator Statistics

	Un-comp Std Dev	Comp Std Dev	Improvement Ratio	Solution Norm
Right Wing	1.039e+0	4.791e-2	21.7	49.3
Left Wing	9.053e-1	6.296e-2	14.4	54.8
Tail	1.290e-1	4.634e-2	2.80	24.1
Lateral Gradient	2.878e+0	1.511e-1	19.0	42.6
Long Gradient	1.048e+1	1.694e-1	61.8	48.5
Memory Slot	11			

Figure of Merit # 1 – Tail Magnetometer (MBc)

	North	East	South	West	Sum
Pitch	0.15	0.10	0.20	0.12	0.57
Roll	0.03	0.03	0.08	0.05	0.19
Yaw	0.05	0.05	0.03	0.08	0.21
Sum	0.25	0.18	0.31	0.25	FOM=0.97nT

Figure of Merit # 2 – Lateral Gradient (GXc)

	North	East	South	West	Sum
Pitch	0.45	0.20	0.12	0.10	0.87
Roll	0.50	0.25	0.12	0.10	0.97
Yaw	0.15	0.25	0.08	0.15	0.63
Sum	1.1	0.70	0.32	0.35	FOM=2.47nT

Figure of Merit # 3 – Longitudinal Gradient (GYc)

	North	East	South	West	Sum
Pitch	0.25	0.15	0.23	0.10	0.73
Roll	0.30	0.20	0.25	0.13	0.88
Yaw	0.08	0.10	0.13	0.08	0.39
Sum	0.63	0.45	0.61	0.31	FOM = 2.00nt

The following plots are graphical representations of the FOM data taken earlier in the year and are also indicative of a good compensation fit to a magnetically clean aircraft.

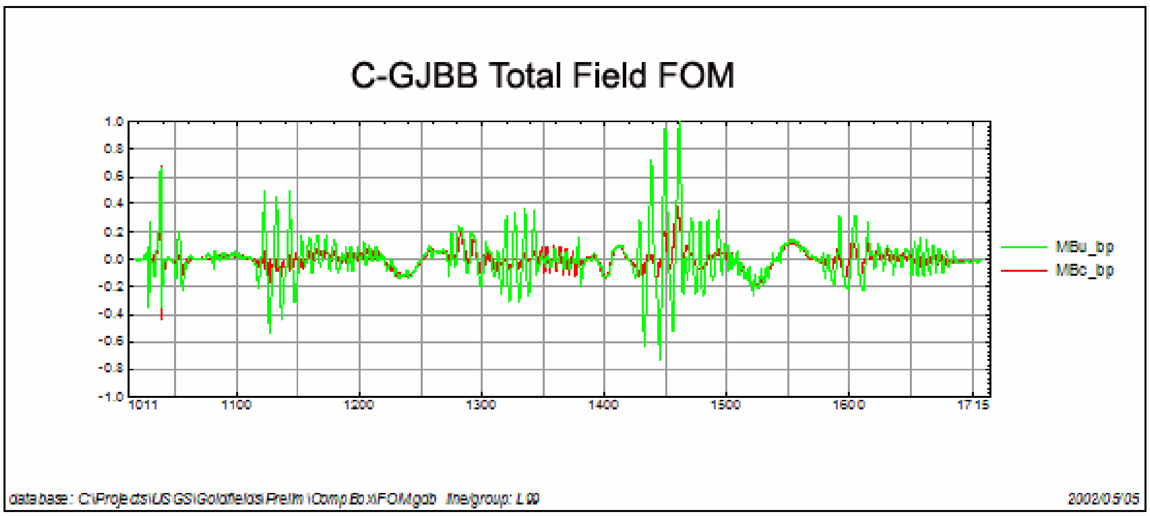


Illustration - C-GJBB Total Field Figure of Merit

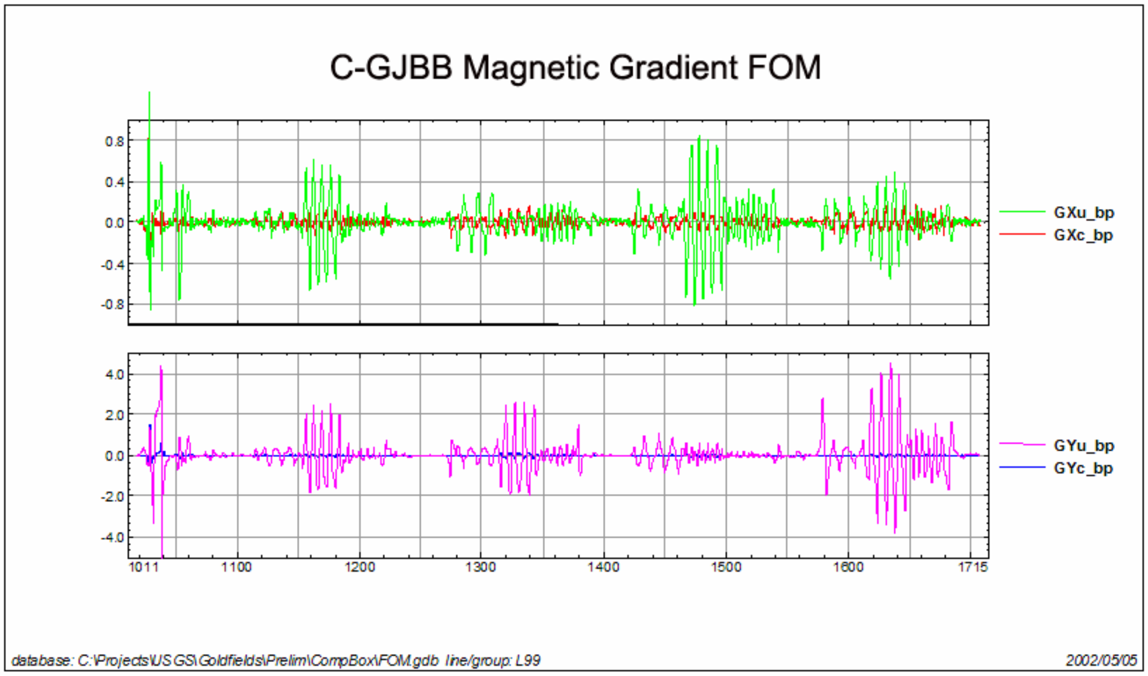


Illustration - C-GJBB Gradients Figure of Merit

4.3 Magnetic Base Station

Two magnetic base stations were used for this survey. One unit was a Geometrics G823B cesium vapor sensor with integral counter and serial interface. A local data logger is used to store the continual field measurements and a radio modem used to transmit the readings to the field office. At the field office the data is plotted graphically and checked automatically for diurnal activity tolerance.

The cesium unit was placed within radio data link range on a hillside estate 6.1 km from the Buena Vista Best Western so that the field crew could monitor diurnal conditions in real time.

The other unit used was a GEM Systems GSM-19 Overhauser Proton magnetometer. It was set up on the airport grounds in Leadville, CO a distance of 45 km from Buena Vista.

The cesium base station's WGS-84, UTM Zone 13 coordinates are as follows:

395464E
4302094N

Illustration – Cesium Base Magnetometer Site

The second proton type base magnetometer was set up near the end of the runway at Leadville Airport. The station was positioned at WGS-84 UTM Z6N coordinates:

386192E
4342518N

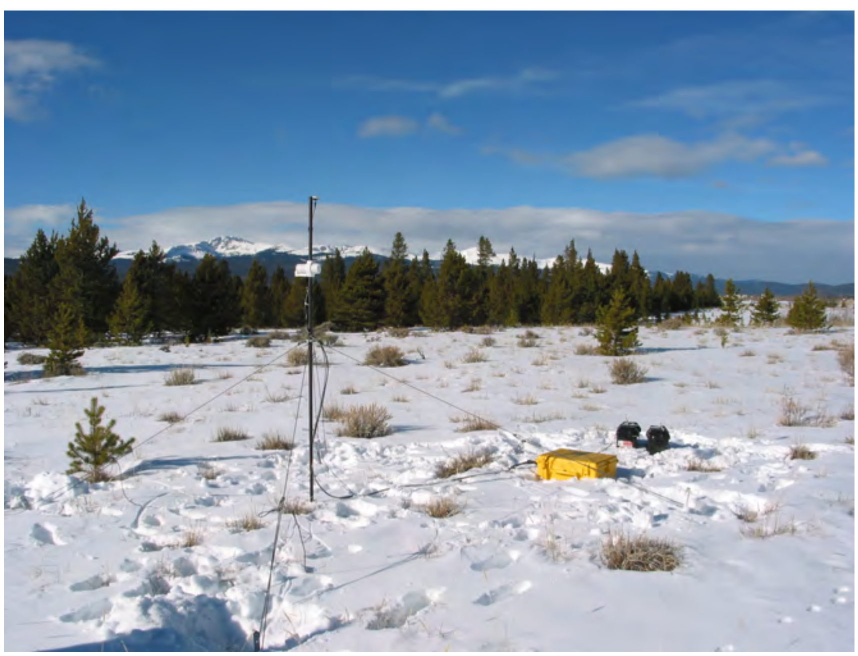


Illustration – Proton Base Magnetometer Site

The base station magnetometers were recorded over 24 hours of quiet magnetic diurnal activity to obtain an average base value.

The mean total field value used to correct with database channel BaseMag1, the cesium magnetometer, was 52972nT.

The mean total field value used to correct with database channel BaseMag2, the proton magnetometer, was 52851nT

These values were used consistently in all subsequent diurnal corrections to the aircraft data. Both the aircraft data acquisition system and the base magnetometer are synchronized to UTC time derived from the aircraft GPS system and recorded in the form of seconds after midnight.

4.4 VLF-EM System

No VLF-EM system was recorded during this survey.

4.5 GPS Positioning System

The GPS receiver in the survey aircraft is a Novatel 3151R Propak 12 channel dual-frequency differential unit that communicates directly with the GEDAS system. The base station GPS is also a dual-frequency Novatel 3151R Propak whose data is logged by a battery powered industrial portable computer. A survey grade GPS base antenna and choke ring is used to minimize multi-path errors. The system can be used for differential positioning in either real-time, or post-corrected mode.

The positioning system also incorporates a Racal Landstar real-time DGPS system that receives real-time differential corrections from an orbiting geo-synchronous communications satellite. These corrections from this device allow 2-5 meter positioning accuracy in real-time. A GPS base station is also recorded during the survey flight to provide a higher level of accuracy and an independent confidence check to the Landstar RT DGPS system.

GPS signals are occasionally “dithered” by the US Department of Defense for security reasons. This dithering can cause positioning errors of up to 100 meters. In addition to dithering, atmospheric and ionospheric effects typically reduce the accuracy of the non-differential positioning to approximately 10 meters RMS. If a suitable stationary GPS receiver on a known, or assumed position, is used to record the apparent errors in the satellite range data, those errors can be used to correct the moving receiver in the aircraft to a an accuracy of 2-5 meters RMS. This compensation process is called differential correction and can be either applied to the moving receiver in real time for higher dynamic accuracy, or applied later to find out where the aircraft *was* with high accuracy. This is called real-time and post-corrected differential positioning respectively.

The GPS base station was setup on the roof peak above room 208. After acquiring data for 24 hours, the averaged position was given as

Latitude:	38° 50’ 56.1887”	ρ = 0.154m
Longitude:	-106° 08’ 10.3009”	ρ = 0.128m
Elevation (MSL):	2435.698m (MSL)	ρ = 0.290m

This base GPS position was further corrected using the program “GrafNav” and data acquired from a base station located 17km away. The station location is published as:

Station:	DSRC
Service:	CORS
Latitude:	39° 59’ 29.152680”
Longitude:	-105° 15’ 39.714120”
Elevation:	2421.946m HAE (height above ellipsoid)

The “DSRC” base station data was used to differentially correct approximately 12 hours of data acquired at our base station location at the Best Western Vista Inn.

The differentially corrected antenna position was computed to be:

Latitude:	**38° 50’ 56.15963”**
Longitude:	**-106° 08’ 10.30262”**
Elevation:	**2421.946.351 (HAE)**

The output from the **USGS Geoid99** model was **–13.882m** resulting in a station height of **2435.828m MSL**

*The USGS Geoid99 model was used to transform Height Above Ellipsoid to Height Above Sea Level

The difference between the above position and the initial averaged position is as follows :

Master Position:	X = 401404.60965 m	Initial Averaged Position	X = 401404.66226 m
	Y = 4300626.01615 m		Y = 4300626.91174 m
	Z = 2435.898 m		Z = 2435.828 m

X = **6cm**
Y = **90cm**
Z = **7cm**

This position agrees to within a meter to the position observed by simple averaging. This is indicative of a differential solution free of systematic errors.

The GPS antenna can be seen on the shorter of the two masts near the roof peak in the illustration below. The longer mast is the VHF radio modem data link antenna.

Illustration – Base Station GPS Antenna and Radio Modem Link

4.6 Radar Altimeter

The radar altimeters used were a Terra TRA-3000 digital unit (database channel RadAlt1) with accuracy of ±3 meters in the range of typical survey altitudes, and a King KRA-10A (RadAlt2) with similar specifications.

4.7 Barometric Altimeter

The barometric altimeter monitored by the system is a Setra model 270 with accuracy of ±1 meters.

4.8 Flight Path Camera

The flight path is recorded by a Panasonic GP-KR222 SV hi-resolution color video camera located in the lower rear fuselage of the aircraft. The video is recorded by a Panasonic AG-1980P SVHS recorder. Data pertaining to position, time, speed, altitude, line number and direction are superimposed in the videotape by a Horita SCT-50 video titler.

4.9 GEDAS Digital Recorder

All data is processed and recorded digitally by our GEDAS system. The GEDAS is an industrial rack-mount Intel Pentium based PC computer operating at 233 MHz with multiple hard-drives, IO ports and ADAC devices.

The GEDAS system records time, magnetic, and VLF data at 10 Hz. All positioning data is recorded at 2Hz. Data files are organized on a flight-by-flight basis in a proprietary binary format. The data is then converted post-flight to a Geosoft compatible format.

Data can be downloaded from the system by either floppy disk or Iomega ZIP disk. Data can be delivered in the field by floppy, ZIP disk, Iomega JAZ disk or CD-ROM.

4.10 Personnel

The following chart illustrates the Goldak Airborne Surveys crewmembers involved in this particular survey.

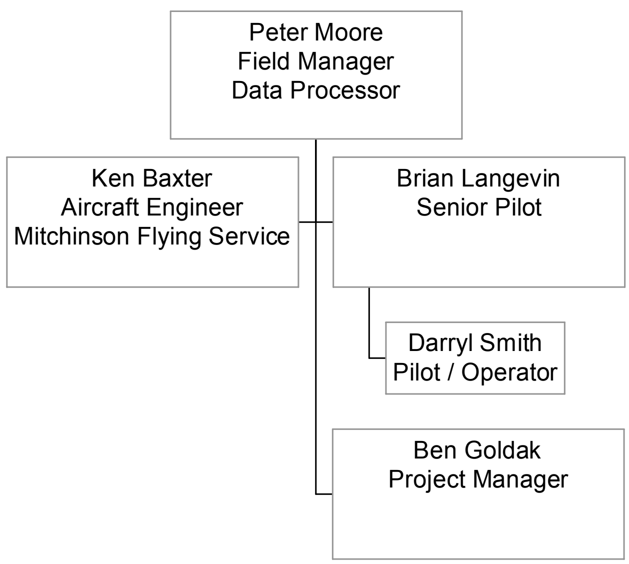


Illustration – Project Personnel

5. DATA PROCESSING AND PRESENTATION

All positions in the database are represented in both the WGS-84 (NAD-83) datum as well as the NAD-27 datum. UTM coordinates are calculated in Zone 10N. All maps are presented in the NAD-27 datum as per contract specification.

Although the line magnetic data is of good quality, and diurnal conditions were light to moderate, the gridded data has many unusual features that do not appear realistic. This is most likely due the many and varied cultural artifacts in the survey area, particularly in the south and western portions of the block. The existence of these artifacts was verified by viewing the flight video.

5.1 Total Field Leveling and Magnetic Gradient Processing

Conventional tie line leveling was carried out on the data at the Goldak Airborne Surveys office in Saskatoon.

The processing consists of the following basic streams:

Positioning processing
Magnetic leveling
Altimeter processing
Layout and production of maps

All data processing and most of the map layout was done in Geosoft Oasis Montaj. Many custom routines have been developed and used to facilitate the process, particularly in map layout.

Each can be discussed separately although there are many interdependencies.

Positioning Data

This data was acquired using Novatel 12 channel dual-frequency GPS receivers. The real-time positioning is enhanced by the use of the Racal Landstar system that provides RTCM-104 corrections to the aircraft GPS receiver during the flight. This increases 3-dimensional accuracy to approximately 3-5 meters in real time.

Post-processing using Waypoint Consulting GrafNav software was done to enhance the positioning accuracy. This step, depending on baseline distance and ionospheric activity, brings accuracy to the 1-meter level.

Flight path is also verifiable by the times and positions superimposed on the flight-path videotape.

The video overlay generated by the GEDAS data system, displays the following data format:

HH:MM:SS.S	MM-DD-YY
LAT TYPE	LON
UTME	UTMN
LOCX	LOCY
LINE#	HAGL
COG	VEL

Were HH:MM:SS.S is the data system time in UTC as set from GPS time at the last line start. MM-DD-YY is the UTC date. LAT and LON are the latest position update from the GPS in decimal degrees. TYPE is either ‘A’ for autonomous, or ‘D’ for a real-time differential type position. UTME and UTMN are the UTM coordinates of the last positioning fix. LOCX and LOCY are the local track coordinates relative to the survey grid origin. LINE# is the line number designation and HAGL is the radar altimeter derived height above the terrain. COG is the GPS indicated track over the ground in degrees true, while VEL is the aircraft velocity in meters per second.

It should be noted that the 10Hz clock display is asynchronous from GPS time and may be subject to drift while on line. The clock is reset at the beginning of every line. The method for determining precise video time is to observe the 10Hz clock at the GPS position change just prior to the event of interest. Note the time of that GPS fix from the data file. Advance the video to the event and note the 10Hz clock again. Subtract the first 10Hz time from the first and add that time to the GPS fiducial time.

Magnetic Data

The first steps in verifying the magnetic data took place in the field. The base station data was monitored to ensure compliance with the contract specification. The fourth difference was also monitored carefully to find any sudden offsets or other problems in the data.

Leveling of the data consisted of the following steps:

- Statistical leveling of the tie lines with linear trend
- Statistical leveling of the survey lines with linear trend
- Repeat statistical leveling in steps 1 and 2 using a piecewise linear interpolation over second order spline to model higher order diurnal effects and positioning errors.
- Move flight path to minimize remaining error as described above.
- Manual leveling to remove remaining errors

Statistical leveling refers to applying linear or smoothly varying offsets to the data to minimize the leveling error. This is required since diurnal corrections are not always spatially consistent.

Given the evidence of smoothly varying diurnal, the linear and second order trend offsets applied to the flight data is reasonable.

Following the statistical leveling to compensate for diurnal and flight path adjustment all remaining leveling offsets can be considered as errors. The major source of error is altitude control.

When adjusting the data to accommodate mis-closures at tie line intersections the intention is to shift the data location in such a way as to avoid offsets or sharp variations in the data. Further refinement of the leveling network was carried out by using the calculated vertical gradient to estimate the magnetic error at intersections where significant altitude errors were present.

A final set of corrections to the data were made after examination of the resulting magnetic field. The calculated vertical gradient showed areas where gradients had along line trends, clearly indicating problems with the leveling. These along line trends can be caused by altitude errors in the flying of the defined drape surface. Small adjustments at this time were sufficient to finalize the leveling network.

Altitude Data

Part of the GPS positioning processing involves calculation of the height above sea level. This component of the position is the least reliable, however with suitable care should be accurate to within 2-3 meters.

The barometric altimeter is calibrated for the air pressure at the beginning of each flight and allowed to drift from that point. The drift is very similar to the magnetic diurnal in that it varies both in time and in space. It is quite possible that the air pressure would vary significantly from one end of the survey block to the other on a large area.

At this point the derived topography was generated for post-processed GPSZ minus radar altitude, gridded and compared with the known topography.

Map Production

The final task in processing this data was the layout and production of maps in Postscript format. The maps are then converted to a device dependant format. HPGL RTL format is used for the HP 750C+ plotter. Both the postscript and the RTL files are included on CDROM.

5.2 Map Presentations

The contract specifies a presentation scale of 1:100,000.

One copy of a Flight Path map with Total Magnetic Intensity (TMI) contours on clear film was generated at a scale of 1:100,000. The magnetic data was presented with the IGRF2000 regional field removed. TF and CVG grid images are shown below.

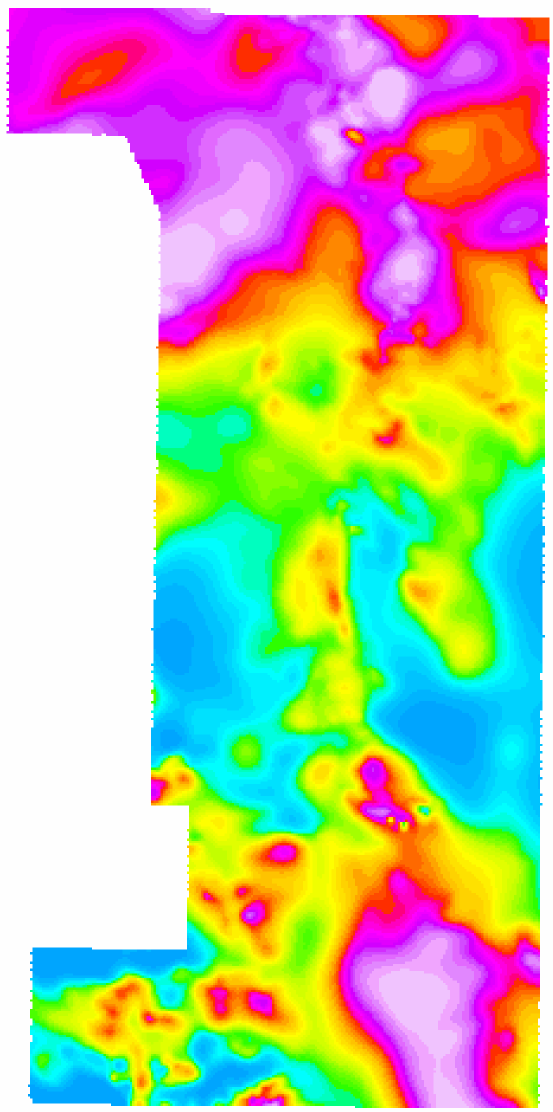


Illustration – Total Magnetic Intensity Image

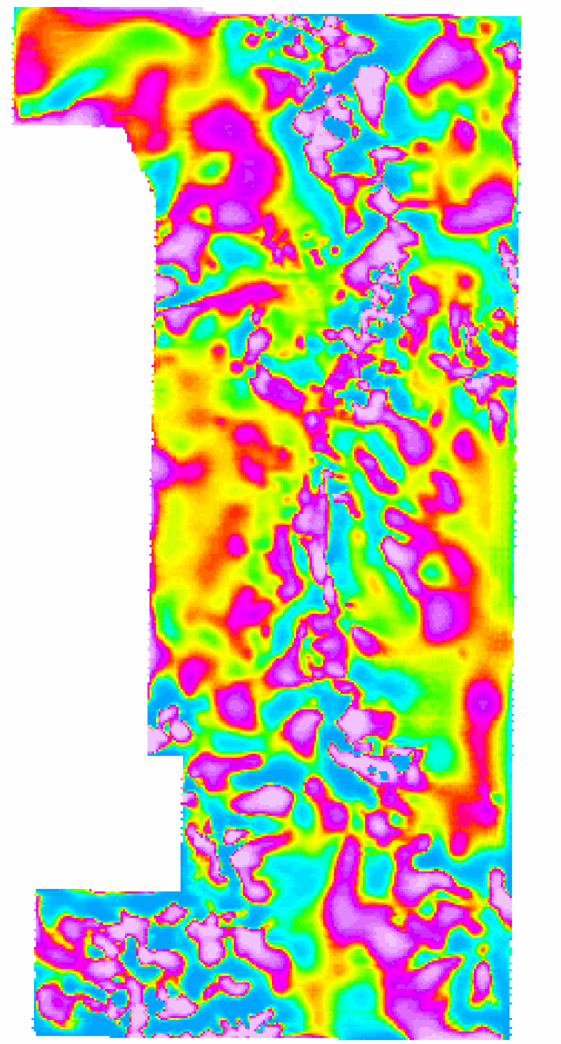


Illustration – Calculated Vertical Gradient Image

5.3 Multi-parameter Analog Profiles

Selected channels have been presented in analog chart style on continuous thermal paper. Included in these channels are Total Field Mag, course and fine scales, longitudinal gradient, as well as lateral and vertical gradients. Also included are the corrected GPS, barometric and radar altitudes as well as the magnetic fourth difference noise for the tail sensor.

5.4 Digital Data Files

All raw and processed data files along with the Geosoft compatible grids are included on CD-ROM disks.

The following is a primary channel definition list for the database. Note that additional temporary, work and special system channels may exist in the database and may be ignored.

BALT	BAROMETRIC ALTIMETER
BaseMag1	DIURNAL BASE MAGNETIC FIELD 1, DE-SPIKED, FILTERED
BaseMag2	DIURNAL BASE MAGNETIC FIELD 2, DE-SPIKED, FILTERED
DATE	CALENDAR DATE
DLat	DIFFERENTIALLY CORRECTED GPS LATITUDE
DLon	DIFFERENTIALLY CORRECTED GPS LONGITUDE
Fiducial	LINE FIDUCIAL COUNTER
GHoriz	TOTAL HORIZONTAL GRADIENT (SUM OF SQUARES)
GTIME	GPS TIME
GXc	LATERAL GRADIENT, COMPENSATED
GXc_Lag	LATERAL GRADIENT, LAGGED
GXn	LATERAL GRADIENT, NORMALIZED
GXu	LATERAL GRADIENT, UNCOMPENSATED
GYc	LONGITUDINAL GRADIENT, COMPENSATED
GYc_Lag	LONGITUDINAL GRADIENT, LAGGED
GYn	LONGITUDINAL GRADIENT, NORMALIZED
GYu	LONGITUDINAL GRADIENT, UNCOMPENSATED
GZ_hp	VERTICAL GRADIENT
GZc	VERTICAL GRADIENT, COMPENSATED
GZc_Lag	VERTICAL GRADIENT, LAGGED
GZn	VERTICAL GRADIENT, NORMALIZED
GZu	VERTICAL GRADIENT, UNCOMPENSATED
IGRF	INTERNATION GEOMAGNETIC REFERENCE FIELD 2000, UPDATED
Line	LINE NUMBER
Lat_27	LATITUDE, NAD27
Lon_27	LONGITUDE, NAD27
Mag_Lev	TIE LINE LEVELED TOTAL FIELD
Mag_Lev_Resid	TIE LINE LEVELED TOTAL FIELD, IGRF REMOVED
MBc	LOWER TAIL MAG, COMPENSATED
MBc_D4	LOWER TAIL MAG, 4TH DIFF NOISE
MBc_DC1	LOWER TAIL MAG, COMPENSATED, DIURNAL 1 CORRECTED
MBc_DC1_resid	LOWER TAIL MAG, COMPENSATED, DIURNAL 1 CORRECTED, IGRF rem.
MBc_DC2	LOWER TAIL MAG, COMPENSATED, DIURNAL 2 CORRECTED
MBc_Lag	LOWER TAIL MAG, COMPENSATED, LAGGED
MBu	LOWER TAIL MAG, UNCOMPENSATED
MLc	LEFT WING MAG, COMPENSATED
MLc_D4	LEFT WING MAG, 4TH DIFF NOISE
MLc_Lag	LEFT WING MAG, COMPENSATED, LAGGED
MLu	LEFT WING MAG, UNCOMPENSATED
MRc	RIGHT WING MAG, COMPENSATED
MRc_D4	RIGHT WING MAG, 4TH DIFF NOISE
MRc_Lag	RIGHT WING MAG, COMPENSATED, LAGGED
MRu	RIGHT WING MAG, UNCOMPENSATED
ONLINE	IN / OUT GRID LOGICAL FLAG
RadarTopo	RADAR ALTIMETER / GPS DERIVED TOPOGRAPHIC ALTITUDE
RALT1A	RADAR ALTIMETER NUMBER 1, ANALOG INPUT
RAlt1A_Lag	RAD ALT 1, LAGGED
RALT2	RADAR ALTIMETER NUMBER 2
RAlt2_Lag	RAD ALT 2, LAGGED
Time_HMS	Time in hours, minutes, seconds
Velocity	AIRCRAFT VELOCITY IN M/S
X	X CHANNEL IN USE

X_27	NAD 27 E
X_84	WGS 84 E
Y	Y CHANNEL IN USE
Y_27	NAD 27 N
Y_84	WGS 84 N

The Geosoft .GDB database is included in the final delivery of digital data. The following channels are also provided in simple uncompressed ASCII .XYZ format. The Geosoft export template used is as follows.

```
[EXPORT XYZ]
EXPORT LINE,NORMAL,10,1
EXPORT DLon,NORMAL,10,5
EXPORT DLat,NORMAL,10,5
EXPORT X,NORMAL,10,1
EXPORT Y,NORMAL,10,1
EXPORT X_84,NORMAL,12,1
EXPORT Y_84,NORMAL,10,1
EXPORT fiducial,NORMAL,10,1
EXPORT DATE,NORMAL,10,1
EXPORT Time_HMS,TIME,14,2
EXPORT Ralt1A_Lag,NORMAL,8,0
EXPORT BALT,NORMAL,8,0
EXPORT DGPSZ,NORMAL,12,1
EXPORT BaseMag1,NORMAL,10,2
EXPORT MBc_Lag,NORMAL,10,2
EXPORT MBc_DC1,NORMAL,10,2
EXPORT MBc_DC1_resid,NORMAL,10,2
EXPORT Mag_Lev,NORMAL,10,2
EXPORT Mag_Lev_Resid,NORMAL,10,2
WRITEDUMMY  NO
WRITEHEADER  YES
CSV_COMMASEPARATE  NO
CLIPMAP     NO
```

Geosoft formats grids in WGS-84 Z10N projection are included and are defined as follows:

TMI	Total Field leveled with minor intersection manipulation. Only intersection adjustments that could be explained by diurnal activity, aircraft altitude errors, etc were made
TMI IGRF Removed	Above data with IGRF2000 subtracted.

The above grids are provided in Geosoft .GRD format as well as simple uncompressed ASCII .GXF format.

5.5 Flight Path Video

Flight path video for this survey is supplied on VHS tapes, one per flight. Times, positions, direction and speed are overlain on the tape for detailed flight path recovery if required. The video format is described above in the processing discussion.

6. DETAILED EQUIPMENT SPECIFICATIONS

Our detailed equipment technical specifications are as follows:

Aircraft

C-GJBB	Piper PA-31 Navajo
	4m composite tail stinger
	Demonstrated Figure of Merit = 0.9nT
	Sensor Separation
	Lateral 582" 14.834m
	Longitudinal 341" 8.661m

Aircraft Magnetometers:

Manufacturer:	Geometrics
Type and Model Number:	Cesium G-822A
Range in nT:	20,000 to 90,000
Sensitivity in nT:	0.005
Sampling Rate:	20Hz

Base Station Magnetometer:

Manufacturer:	GEM Systems
Type and Model Number:	Overhauser GSM-19W
Range in nT:	20,000 to 120,000
Sensitivity in nT:	0.01
Sampling Rate:	5Hz maximum (0.5Hz typical)
Solar Power Supply:	1 - Solarex MSX50

Real-time Magnetic Compensator:

Manufacturer:	RMS Instruments
Type and Model Number:	AADCII
Range in nT:	20,000 to 100,000
Resolution in nT:	0.001
Sampling Rate:	20Hz

Digital Acquisition System:

Manufacturer:	Goldak Exploration Technology
Type and Model Number:	GEDAS
Sampling Rate:	20Hz
Data Format:	GEDAS binary

Positioning Cameras:

Manufacturer:	Panasonic
Model:	GPKR402 HRSV
Lens:	WV-LR4R5 4.5mm
	FOV at 1000 feet AGL is 1040 x 1300 feet

Barometric Altimeter:

Manufacturer:	Setra
Type and Model Number:	270
Range:	-1000 to 10,000 feet
Resolution:	1 meter

Radar Altimeter 1:

Manufacturer	Thompson CSF
Type and Model Number:	ERT-160

Range:	0-8000 feet
Resolution:	1 meter
Accuracy:	1-2%

Radar Altimeter 2:

Manufacturer	Terra
Type and Model Number:	TRA300 – TRI40
Range:	0-2500 feet
Resolution:	1 meter
Accuracy:	5-7%

Positioning System:

Manufacturer:	Goldak Exploration Technology Ltd.
Type and Model Number:	GEDAS
Displays:	10” color LCD graphical display Graphic LCD pilot indicator

GPS Subsystem:

GPS Receiver:

Manufacturer	Novatel
Type and Model Number:	3151R Propak Dual Frequency

GPS Real Time Differential Receiver:

Manufacturer	Racal
Type and Model Number:	Landstar

GPS Base Station:

Manufacturer	Novatel
Type and Model Number:	3151R Propak Dual Frequency

System Resolution:	1 meter
Overall accuracy:	3 m in real-time, <1m post-corrected

Computers:

Manufacturer:	Compaq
Type and Model Number:	Pentium 400, laptop PC
Manufacturer:	Toshiba
Type and Model Number:	Pentium III, 100CS laptop PC

Plotters and Printers:

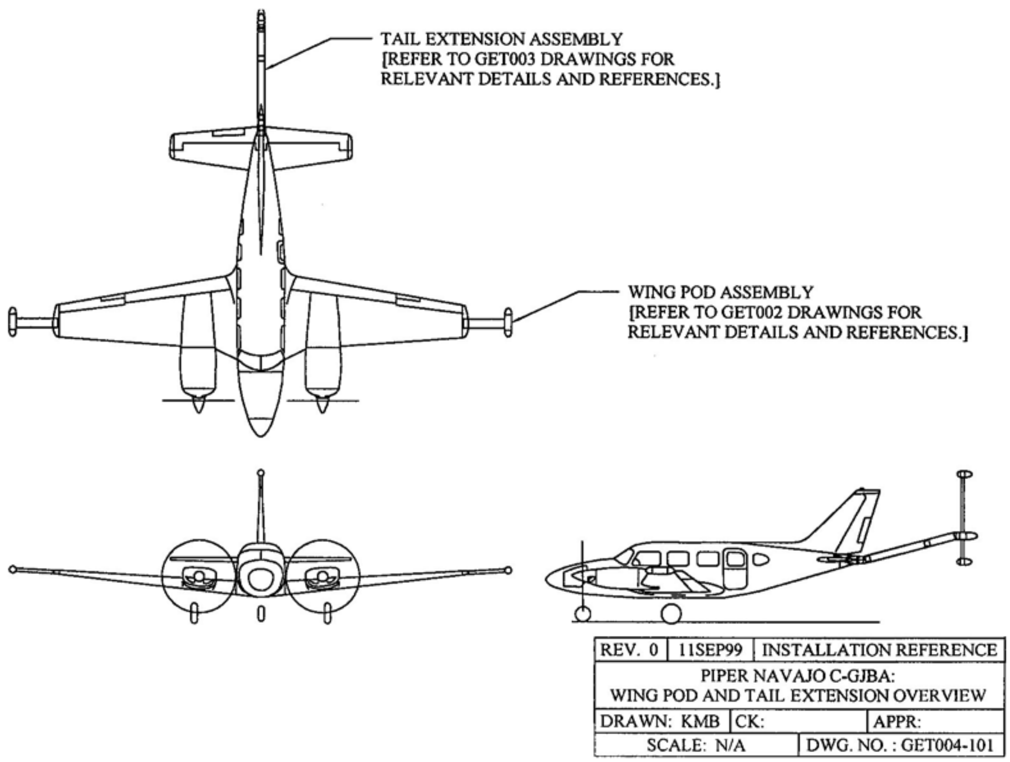
Manufacturer:	Canon
Type and Model Number:	Bubblejet, BJC10 color page printer

Data backup:

Manufacturer:	Iomega
Type and Model Number:	100Mb Zip drive
Manufacturer:	Iomega
Type and Model Number:	1.0Gb Jaz drive
Manufacturer:	Hewlett Packard
Type and Model Number:	Sure Store CD-ROM writer

Software

Manufacturer:	Geosoft
Function:	Geophysical data processing
Type and Model Number:	Oasis Montaj
Manufacturer:	Waypoint Consulting
Function:	GPS post-processing
Type and Model Number:	GrafNav
Manufacturer:	Geomatics Canada
Function:	GPS post-processing
Type and Model Number:	GPSPace



7. STATEMENT OF QUALIFICATIONS

Ben Goldak

I reside at 25 Duncan Crescent in Saskatoon, Saskatchewan.

I hold a B.Sc. Adv. in Computer Science from the University of Saskatchewan.

I have been active in the field of geophysics since 1980.

I have examined the data referred to in this report and find it to be of suitable quality for purposes of geological interpretation.

I am President of Goldak Exploration Technology Ltd.

Ben Goldak April 25, 2003