BAIGENT GEOSCIENCES

Haddington Resources Limited
Liberator and Long Island
Geophysical Survey
Processing Report

December 2009

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1. Datum Specification

The output survey coordinates are based on the Geocentric Datum of Australia 1994 (GDA94), zone 52.

It has the following parameters:

Projection name:	Map Grid of Australia
Datum:	Geocentric Datum of Australia (GDA94)
Reference Frame:	ITRF92 (International Terrestrial Reference 1992)
Epoch:	1994.0
Ellipsoid:	GRS80
Semi-major axis:	6.378.137.0 metres
Inverse flattening:	298,257222101
False Northing:	10,000,000 m N
False Easting:	500,000 m E
Scale Factor:	0.9996

2. Parallax

Parallax corrections were applied as follows:

1. 0 fiducials (at 20 hertz) for magnetics data.
2. 0 fiducials (at 20 hertz) for elevation data.
3. 0.25 seconds for radiometrics

3. Magnetic processing

3.1 Processing Flow

The diurnal base station data was checked for spikes and steps, and suitably filtered prior to the removal of diurnal variations from the aircraft magnetic data.

The diurnal data was filtered with a second difference filter to identify and remove spikes of less than 0.05nT. A second smoothing filter, a 13 point moving average filter is used to reduce noise levels.

The filtered diurnal are then applied to the survey data by synchronising the diurnal data time with the aircraft survey time. The average diurnal base station value was added to the survey data.

An eighth difference filter was run on the raw magnetic survey data in order to identify any remaining spikes in the data, which were manually edited from the data.

The X and Y positioning of the data was then checked for spikes before applying the IGRF correction. Any spikes in the positions were manually edited.

The IGRF 2005 (updated to (2009.87) correction was calculated at each data point taking into account the height above sea level using the gps altitude. This regional magnetic gradient was subtracted from the survey data points.

The data was then tie-line levelled and micro-levelled.

3.2 Compensation

The data was compensated post flight using a 16 term model based on the work done by C.D. Hardwick.

Magnetic compensation sequences were flown after acquisition completed and after routine maintenance was performed, as required. The resulting coefficients were used for post flight magnetic compensation:

Aircraft	Date	Flight	StDev (UnC)	StDev (Cmp)	IR
VH-AVN	10/11/09	1	4.698	0.146	32.11

UNC: Standard deviation of uncompensated TMI (nT)
CMP: Standard deviation of compensated TMI (nT)
IR: Improvement ratio (UNC/CMP)

A qualitative measure of the effectiveness of the compensation is to examine the standard deviation of the high passed total magnetic field before and after the compensation coefficients have been applied. The higher the improvement ratio the better the compensation model has removed the aircraft induced manoeuvre signal. This may not always the case, as a very clean aircraft will have a low improvement ratio. Also if the manoeuvres are smaller than specified then the IR ratio will be small. After reviewing the data, the compensation was deemed to be successful.

3.3 Magnetic Model

IGRF was removed using the N-value corrected gps altitude.

The magnetic model for the centre of the area is detailed below:

Model	IGRF 2005 updated to 2009.87
Declination	3.57941 degrees
Inclination	-41.67359 degrees
Field strength	46947.88 nT
Grid zone	52
Grid central meridian	129.00000 degrees
Input latitude	-13.59216 degrees
Input longitude	131.36366 degrees
Grid convergence	0.55548 degrees
Grid magnetic angle	4.13489 degrees
Secular variation	-0.01150 degrees

3.4 Diurnal Base Value

The average diurnal base value was 46,962.96 nT

3.5 Tie Line levelling Method

Tie line levelling was applied to the data by least squares minimisation, using a polynomial fit of order 0, of the differences in elevation values at the crossover points of the survey traverse and tie line data.

The least squares tie line levelling process employs a two pass Gauss-Seidel iterative scheme. The essential steps in this process are:

In the first pass the tie lines were first adjusted to minimise, in the least squares sense, the crossover values with the traverse line values being held constant.

The second pass held the levelled tied line values constant, and minimised in the least squares sense, the crossover values with traverses.

The DC correction values to be applied to the traverse lines and tie lines were then applied to the magnetic data.

To reduce the effects of radar altimeter and gps errors on the recorded elevation data at the crossover points, data having a radar altimeter difference greater than 15 metres in a radius of 50 metres on the traverse or tie lines were excluded from the tying process.

3.6 Micro-levelling Method

Micro-levelling techniques were then selectively applied to the tie line levelled data to remove minor residual variations in profile intensity Selective micro-levelling was applied in order to leave unaffected any data having no residual levelling artefacts. Selective micro-levelling proceeds using the following steps:

Areas of interest that required micro-levelling were identified through the use of image processing visualisation.

Polygons were used to define areas requiring micro-levelling.

“Pseudo-ties” were constructed from the gridded data by extracting traverses from the grid normal to the flight direction.

Line dependent artefacts were removed from the pseudo lines using custom filters.

Crossover values were calculated between traverse lines and pseudo tie lines.

The traverse lines were adjusted in the pre-defined sections to minimise the crossover values.

This process was repeated in order to remove various wavelength line dependent artefacts from the pseudo-ties. The object of each micro-levelling iteration was to produce a smooth control surface to which the traverse lines are levelled. This control surface was provided through the use of “pseudo-ties”.

3.7 Interpolation Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs 1974, Briggs I. C.: Machine contouring using minimum curvature. *Geophysics*. Vol. 39, No. 1. February 1974. pp. 39-48.

The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel Smith, W. H. F, and P. Wessel, 1990, Gridding with continuous curvature splines in tension, Geophysics 55, 293-305.

A tension factor of 0 was used to interpolate the data.

The mesh size for data interpolation was 10 x 10 metres.

4. Radiometric Processing

4.1 Processing Flow

The processing steps radiometric data were as follows:

1. Application of necessary parallax corrections to data
2. Check radar altimeter data for spikes
3. NASVD spectral smoothing

- Examine the output to determine the number of components required.
- Select 7 components for spectral reconstruction.

4. Standard 256 channel radiometric corrections:

- Dead-time correction performed on 256 channel data.
- Check if energy recalibration required
- Remove 256 channel aircraft and cosmic backgrounds from the data
- Remove background radon from window data using Minty's method (1996)
- Perform STP height corrected spectral stripping
- Perform STP height correction of window data to specified survey height (25m).

5. Micro-levelling

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4.2 Window Energy Limits

The energy bounds for the windows were

Window Name	**Energy Range (Mev)**
Potassium	1.374 – 1.566
Thorium	2.416 – 2.799
Uranium	1.662 – 1.854
Total Count	0.414 – 2.799

4.3 Spectral Stripping Ratios

The stripping ratios used in the processing were:

Alpha	0.277
Beta	0.408
Gamma	0.776
a	0.045
b	0.001
g	0.000

4.4 Aircraft, Cosmic Backgrounds and Height Attenuation coefficients

	Total Count	Potassium	Uranium	Thorium
Aircraft Bkg	399..3	44.3	18.5	6.0
Cosmic Bkg	1.484	0.084	0.075	0.059
Height Attn	-0.007434	-0.009432	-0.008428	-0.007510

The above values are for the windows only. During processing the equivalent 256 channel aircraft and cosmic backgrounds are removed.

4.5 Conversion to Ground Concentrations

	Total Count Cps to Dose rate	Potassium Cps to Percent	Uranium Cps to PPM	Thorium Cps to PPM
Conversion Factor	86.042	350.696	22.740	16.456

4.6 Tie Line Levelling

No tie line levelling was applied.

4.7 Micro-levelling Method

Micro-levelling techniques were then selectively applied to the tie line levelled data to remove minor residual variations in profile intensity Selective micro-levelling was applied in order to leave unaffected any data having no residual levelling artifacts. Selective micro-levelling proceeds using the following steps:

Areas of interest that required micro-levelling were identified through the use of image processing visualisation.

Polygons were used to define areas requiring micro-levelling.

“Pseudo-ties” were constructed from the gridded data by extracting traverses from the grid normal to the flight direction.

Line dependent artefacts were removed from the pseudo lines using custom filters.

Crossover values were calculated between traverse lines and pseudo tie lines.

The traverse lines were adjusted in the pre-defined sections to minimise the crossover values.

This process was repeated in order to remove various wavelength line dependent artefacts from the pseudo-ties. The object of each micro-levelling iteration was to produce a smooth control surface to which the traverse lines are levelled. This control surface was provided through the use of “pseudo-ties”.

4.8 Interpolation Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs 1974, Briggs I. C.: Machine contouring using minimum curvature. *Geophysics*. Vol. 39, No. 1. February 1974. pp. 39-48.

The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel Smith, W. H. F, and P. Wessel, 1990, Gridding with continuous curvature splines in tension, Geophysics 55, 293-305.

A tension factor of 0 was used to interpolate the data.

The mesh size for data interpolation was 25 x 25 metres

5. Elevation Processing

5.1 Processing Flow

The processing steps for digital elevation data were as follows:

1. Application of necessary parallax corrections to data
2. Calculation of raw digital elevation data by subtracting the radar altimeter from the gps altitude
3. Tie line levelling
4. Micro-levelling

5.2 Tie Line levelling Method

Tie line levelling was applied to the data by least squares minimisation, using a polynomial fit of order 0, of the differences in elevation values at the crossover points of the survey traverse and tie line data.

The least squares tie line levelling process employs a two pass Gauss-Seidel iterative scheme. The essential steps in this process are:

In the first pass the tie lines were first adjusted to minimise, in the least squares sense, the crossover values with the traverse line values being held constant.

The second pass held the levelled tied line values constant, and minimised in the least squares sense, the crossover values with traverses.

The DC correction values to be applied to the traverse lines and tie lines were then applied to the magnetic data.

To reduce the effects of radar altimeter and gps errors on the recorded elevation data at the crossover points, data having a radar altimeter difference greater than 15 metres in a radius of 50 metres on the traverse or tie lines were excluded from the tying process.

5.3 Micro-levelling Method

Micro-levelling techniques were then selectively applied to the tie line levelled data to remove minor residual variations in profile intensity Selective micro-levelling was applied in order to leave unaffected any data having no residual levelling artefacts. Selective micro-levelling proceeds using the following steps:

Areas of interest that required micro-levelling were identified through the use of image processing visualisation.

Polygons were used to define areas requiring micro-levelling.

“Pseudo-ties” were constructed from the gridded data by extracting traverses from the grid normal to the flight direction.

Line dependent artefacts were removed from the pseudo lines using custom filters.

Crossover values were calculated between traverse lines and pseudo tie lines.

The traverse lines were adjusted in the pre-defined sections to minimise the crossover values.

This process was repeated in order to remove various wavelength line dependent artefacts from the pseudo-ties. The object of each micro-levelling iteration was to produce a smooth control surface to which the traverse lines are levelled. This control surface was provided through the use of “pseudo-ties”.

5.4 Interpolation Method

The interpolation used is a minimum curvature algorithm. The algorithm is based on the worked published by Briggs 1974, Briggs I. C.: Machine contouring using minimum curvature. *Geophysics*. Vol. 39, No. 1. February 1974. pp. 39-48..

The algorithm has been modified to include a tension parameter based on the work published by Smith and Wessel Smith, W. H. F, and P. Wessel, 1990, Gridding with continuous curvature splines in tension, Geophysics 55, 293-305.

A tension factor of 0 was used to interpolate the data.

The mesh size for data interpolation was 10 x 10 metres.

6. Deliverable Items

The deliverable items included all digital data. The located data conformed to ASEG-GDF format and the gridded data was suppled in ERMapper format. The description of the located data is below.

There were two area processed:

Liberator

Long Island

Located data supplied in ASEG GDF

File name	Definition
*_magdtm	Magnetics and Elevation data
*_rads	Radiometric data
*_rad256	Raw 256 channel data

Gridded data supplied in ER Mapper format

File name	Definition	Units
*_tmi	Final magnetic gridded data	nT
*_elev	Final dtm gridded data	m
*_tot	Final radiometric dose rate gridded data	nGy/hr
*_pot	Final radiometric potassium gridded data	percent
*_ura	Final radiometric uranium gridded data	ppm
*_th	Final radiometric thorium gridded data	ppm

* denotes the area name

Also provided were grids of both areas combined

6.1 Magnetic and elevation Located Data file

```
COMM
COMM  Baigent Geosciences Pty. Ltd.
COMM  ----------------------------
COMM
COMM  LOCATED DATA
COMM  -------------
COMM Area  :   Liberator
COMM Company Flown by:   Thomson Aviation Pty. Ltd.
COMM Company Flown for:  Haddington Resources
COMM Company Processed:  Baigent Geosciences Pty. Ltd.
COMM
COMM AIRBORNE SURVEY EQUIPMENT:
COMM -------------------------
COMM
COMM Aircraft                          : Airtractor
COMM Magnetometer                      : Geometrics G822 Cesium  Vapour
COMM Magnetometer Resolution           : 0.001 nT
COMM Magnetometer Compensation         : Post Flight
COMM Magnetometer Sample Interval      : 20 Hz, Approx 3.00 metres
COMM Data Acquisition                  : GeoOZ Model 2007
COMM Spectrometer                      : Radiation Solutions RS 500
COMM Crystal Size                      : 64 lt downward array
COMM Spectrometer Sample Interval      : 0.5 Seconds (approx 30 metres)
COMM GPS Navigation System             : Novatel 951R GPS Receiver
COMM
COMM
COMM
COMM
COMM AIRBORNE SURVEY SPECIFICATIONS
COMM
COMM Flight Line Direction             :    045 - 225  degrees
COMM Flight Line Separation            :           50  metres
COMM Tie Line Direction                :    135 - 315  degrees
COMM Tie Line Separation               :           500 metres
COMM Terrain Clearance                 :       30 metres (MTC)
COMM
COMM
COMM Survey flown                      :        November 2009
COMM
COMM
COMM Flight path calculated from differentially
COMM corrected GPS Data using a Novatel 951R GPS Receiver.
COMM
COMM
COMM Grid notation refers to GDA/MGA Zone  52
COMM
COMM
COMM MAGNETIC DATA CORRECTIONS:
COMM -------------------------
COMM Diurnal variations removed
COMM IGRF(2005) updated to 2009.87 removed
COMM Average survey base station value added to datum
COMM
COMM RADIOMETRIC CORRECTIONS AND COEFFICIENTS:
COMM ----------------------------------------
COMM Spectral data preprocessed using NASVD
COMM Data has been corrected for aircraft and cosmic backgrounds.
COMM Height corrected to a constant datum of 35 metres,
```

```
COMM minimum height of 20 and a maximum of 300 metres.
COMM Data has also been corrected for radon using the method described by Minty
COMM and corrected for channel interaction.
COMM
COMM                    Tot.Count    Potassium   Uranium     Thorium
COMM Arcft Bkg            155.53        23.58      6.047         0
COMM Cosmic Bkg           0.986        0.0514      0.041       0.0549
COMM Height Attn         0.007434    0.009432     0.008428    0.007510
COMM CPS to equivalents    57.789     230.992     19.669      11.896
COMM
COMM
COMM STRIPPING RATIOS:
COMM ----------------
COMM   Alpha = 0.276,  Beta = 0.418, Gamma = 0.759,
COMM   a = 0.048,  b = 0.003,  g = 0.001
COMM
COMM  Field Name                    Format         Units     Null Value
COMM
COMM  BGS Job Number               a5
COMM  Line number                  a8
COMM  Flight number                i4
COMM  Flight date                  a8
COMM  fiducial                      f12.1                        -999999.0
COMM  mga_east                      f10.2          METRES        -99999.00
COMM  mga_north                     f11.2          METRES        -99999.00
COMM  wgs84_lat                     f12.7          DEGREES       -99.000000
COMM  wgs84_long                    f13.7          DEGREES       -999.00000
COMM  raw_mag                       f10.3          nT            -9999
COMM  mag_gammas                    f10.3          nT            -9999.000
COMM  diurnal_gammas                f10.3          nT            -9999.000
COMM  igrf_gammas                   f10.3          nT            -9999.000
COMM  mag_level                     f10.3          nT            -9999.000
COMM  rad_alt                       f8.2           METRES        -999.00
COMM  gps_height                    f8.2           METRES        -999.00
COMM  dtm                           f8.2           METRES        -999.00
```

6.2 Radiometric Located Data file

```
COMM
COMM  Baigent Geosciences Pty. Ltd.
COMM  ----------------------------
COMM
COMM  LOCATED DATA
COMM  -------------
COMM Area  :   Liberator
COMM Company Flown by:   Thomson Aviation Pty. Ltd.
COMM Company Flown for:  Haddington Resources
COMM Company Processed:  Baigent Geosciences Pty. Ltd.
COMM
COMM AIRBORNE SURVEY EQUIPMENT:
COMM ------------------------
COMM
COMM Aircraft                        : Airtractor
COMM Magnetometer                    : Geometrics G822 Cesium  Vapour
COMM Magnetometer Resolution         : 0.001 nT
COMM Magnetometer Compensation       : Post Flight
```

```
COMM Magnetometer Sample Interval     : 20 Hz, Approx 3.00 metres
COMM Data Acquisition                 : GeoOZ Model 2007
COMM Spectrometer                     : Radiation Solutions RS 500
COMM Crystal Size                     : 64 lt downward array
COMM Spectrometer Sample Interval     : 0.5 Seconds (approx 30 metres)
COMM GPS Navigation System            : Novatel 951R GPS Receiver
COMM
COMM
COMM
COMM
COMM AIRBORNE SURVEY SPECIFICATIONS
COMM
COMM Flight Line Direction            :    045 - 225  degrees
COMM Flight Line Separation           :           50  metres
COMM Tie Line Direction               :    135 - 315  degrees
COMM Tie Line Separation              :           500 metres
COMM Terrain Clearance                :       30 metres (MTC)
COMM
COMM
COMM Survey flown                     :        November 2009
COMM
COMM
COMM Flight path calculated from differentially
COMM corrected GPS Data using a Novatel 951R GPS Receiver.
COMM
COMM
COMM Grid notation refers to GDA/MGA Zone  52
COMM
COMM
COMM MAGNETIC DATA CORRECTIONS:
COMM -------------------------
COMM Diurnal variations removed
COMM IGRF(2005) updated to 2009.87 removed
COMM Average survey base station value added to datum
COMM
COMM RADIOMETRIC CORRECTIONS AND COEFFICIENTS:
COMM ---------------------------------------
COMM Spectral data preprocessed using NASVD
COMM Data has been corrected for aircraft and cosmic backgrounds.
COMM Height corrected to a constant datum of 30 metres,
COMM minimum height of 10 and a maximum of 300 metres.
COMM Data has also been corrected for radon using the method described by Minty
COMM and corrected for channel interaction.
COMM
COMM                   Tot.Count    Potassium   Uranium     Thorium
COMM Arcft Bkg           399.3        44.3       18.5         6.0
COMM Cosmic Bkg          1.484        0.084      0.075       0.059
COMM Height Attn        0.007434    0.009432     0.008428    0.007510
COMM CPS to equivalents   86.042     350.696     22.740      16.456
COMM
COMM
COMM STRIPPING RATIOS:
COMM ----------------
COMM   Alpha = 0.276,  Beta = 0.418, Gamma = 0.759,
COMM   a = 0.048,  b = 0.003,  g = 0.001
COMM
COMM  Field Name                    Format         Units     Null Value
COMM
COMM  BGS Job Number               a5
COMM  Line number                  a8
COMM  Flight number                i4
```

```
COMM  Flight date                  a8
COMM  fiducial                      f12.1                          -999999.0
COMM  mga_east                      f10.2          METRES          -99999.00
COMM  mga_north                     f11.2          METRES          -99999.00
COMM  wgs84_lat                     f12.7          DEGREES         -99.000000
COMM  wgs84_long                    f13.7          DEGREES         -999.00000
COMM  rad_alt                       f8.2           METRES          -999.00
COMM  temp_air_deg_c                f5.1           DEG             -9.0
COMM  baro_pressure                 f8.2           hPa             -999.0
COMM  gps_height                    f8.2           METRES          -999.00
COMM  live_time                     f6.0           MSEC            -9999
COMM  raw_tot_cps                   f8.0           CPS             -99.
COMM  raw_pot_cps                   f7.0           CPS             -99.
COMM  raw_ura_cps                   f7.0           CPS             -99.
COMM  raw_th_cps                    f7.0           CPS             -99.
COMM  cosmicd_cps                   f6.0           CPS             -999
COMM  dose_rate                     f10.4          nGy/h           -999.0000
COMM  pot_percent                   f9.4           PERCENT         -99.0000
COMM  ura_ppm                       f9.4           PPM             -99.
COMM  th_ppm                        f9.4           PPM             -99.000
```

6.3 256 Radiometric Located Data file

```
COMM
COMM  Baigent Geosciences Pty. Ltd.
COMM  -----------------------------
COMM
COMM  LOCATED DATA
COMM  -------------
COMM Area  :   Liberator
COMM Company Flown by:   Thomson Aviation Pty. Ltd.
COMM Company Flown for:  Haddington Resources
COMM Company Processed:  Baigent Geosciences Pty. Ltd.
COMM
COMM AIRBORNE SURVEY EQUIPMENT:
COMM -------------------------
COMM
COMM Aircraft                          : Airtractor
COMM Magnetometer                      : Geometrics G822 Cesium  Vapour
COMM Magnetometer Resolution           : 0.001 nT
COMM Magnetometer Compensation         : Post Flight
COMM Magnetometer Sample Interval      : 20 Hz, Approx 3.00 metres
COMM Data Acquisition                  : GeoOZ Model 2007
COMM Spectrometer                      : Radiation Solutions RS 500
COMM Crystal Size                      : 64 lt downward array
COMM Spectrometer Sample Interval      : 0.5 Seconds (approx 30 metres)
COMM GPS Navigation System             : Novatel 951R GPS Receiver
COMM
COMM
COMM
COMM
COMM AIRBORNE SURVEY SPECIFICATIONS
COMM
COMM Flight Line Direction             :    045 - 225  degrees
```

```
COMM Flight Line Separation           :           50  metres
COMM Tie Line Direction               :    135 - 315  degrees
COMM Tie Line Separation              :           500 metres
COMM Terrain Clearance                :       30 metres (MTC)
COMM
COMM
COMM Survey flown                     :        November 2009
COMM
COMM
COMM Flight path calculated from differentially
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COMM Grid notation refers to GDA/MGA Zone  52
COMM
COMM
COMM MAGNETIC DATA CORRECTIONS:
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COMM IGRF(2005) updated to 2009.87 removed
COMM Average survey base station value added to datum
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COMM Height corrected to a constant datum of 30 metres,
COMM minimum height of 10 and a maximum of 300 metres.
COMM Data has also been corrected for radon using the method described by Minty
COMM and corrected for channel interaction.
COMM
COMM                    Tot.Count    Potassium   Uranium     Thorium
COMM Arcft Bkg            399.3        44.3       18.5         6.0
COMM Cosmic Bkg           1.484        0.084      0.075       0.059
COMM Height Attn         0.007434    0.009432     0.008428    0.007510
COMM CPS to equivalents   86.042     350.696     22.740      16.456
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COMM
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COMM   Alpha = 0.276,  Beta = 0.418, Gamma = 0.759,
COMM   a = 0.048,  b = 0.003,  g = 0.001
COMM
COMM  Field Name                    Format         Units     Null Value
COMM
COMM  BGS Job Number               a5
COMM  Line number                  a8
COMM  Flight number                i4
COMM  Flight date                  a8
COMM  fiducial                      f12.1                          -999999.0
COMM  mga_east                      f10.2          METRES          -99999.00
COMM  mga_north                     f11.2          METRES          -99999.00
COMM  wgs84_lat                     f12.7          DEGREES         -99.000000
COMM  wgs84_long                    f13.7          DEGREES         -999.00000
COMM  rad_alt                       f8.2           METRES          -999.00
COMM  temp_air_deg_c                f5.1           DEG             -9.0
COMM  baro_pressure                 f8.2           hPa             -999.0
COMM  gps_height                    f8.2           METRES          -999.00
COMM  live_time                     f6.0           MSEC            -9999
COMM  cosmicd_cps                   f6.0           CPS             -999
COMM  256 channel raw spectra    256f6.0           CPS             -9
```
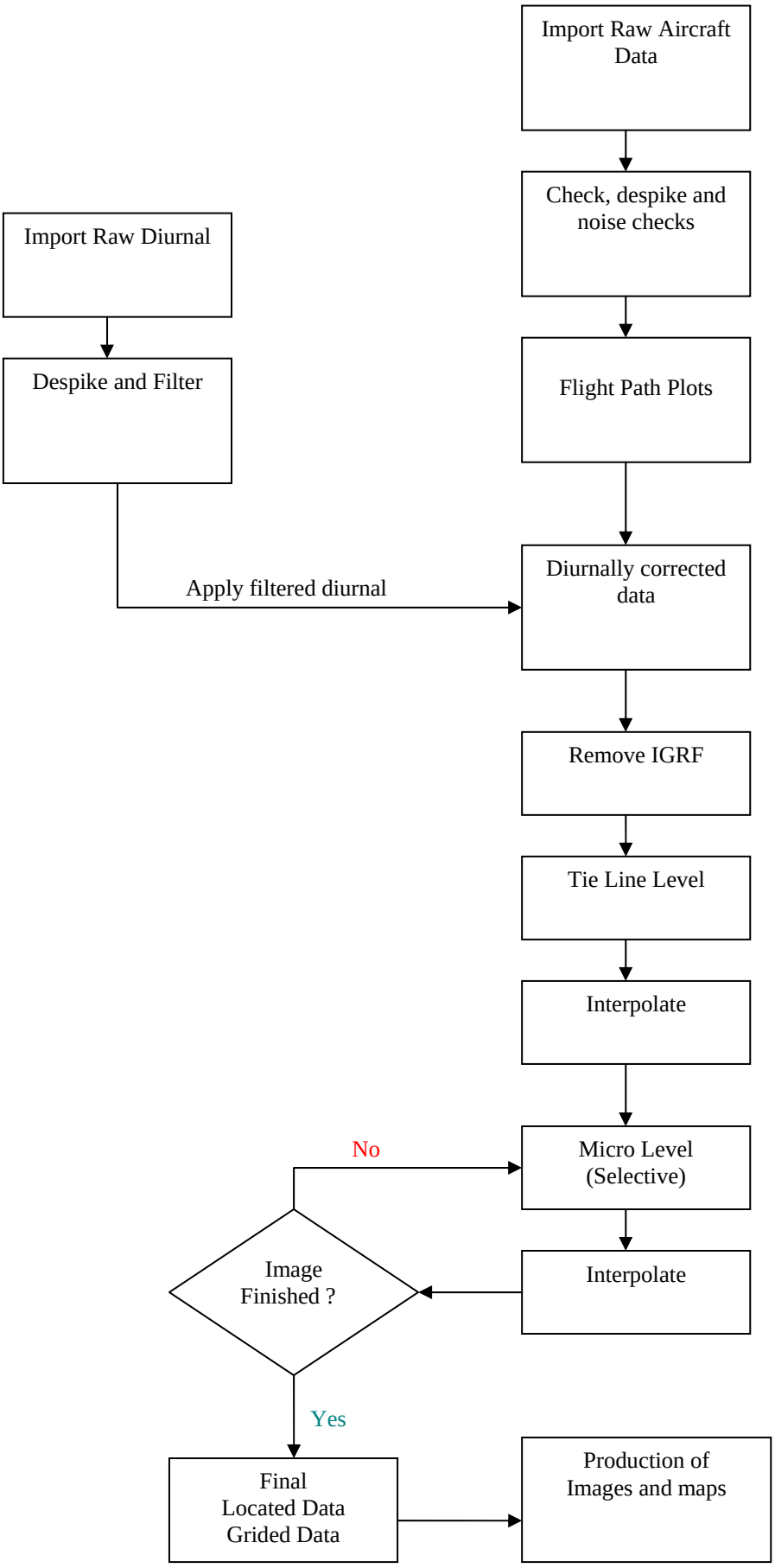
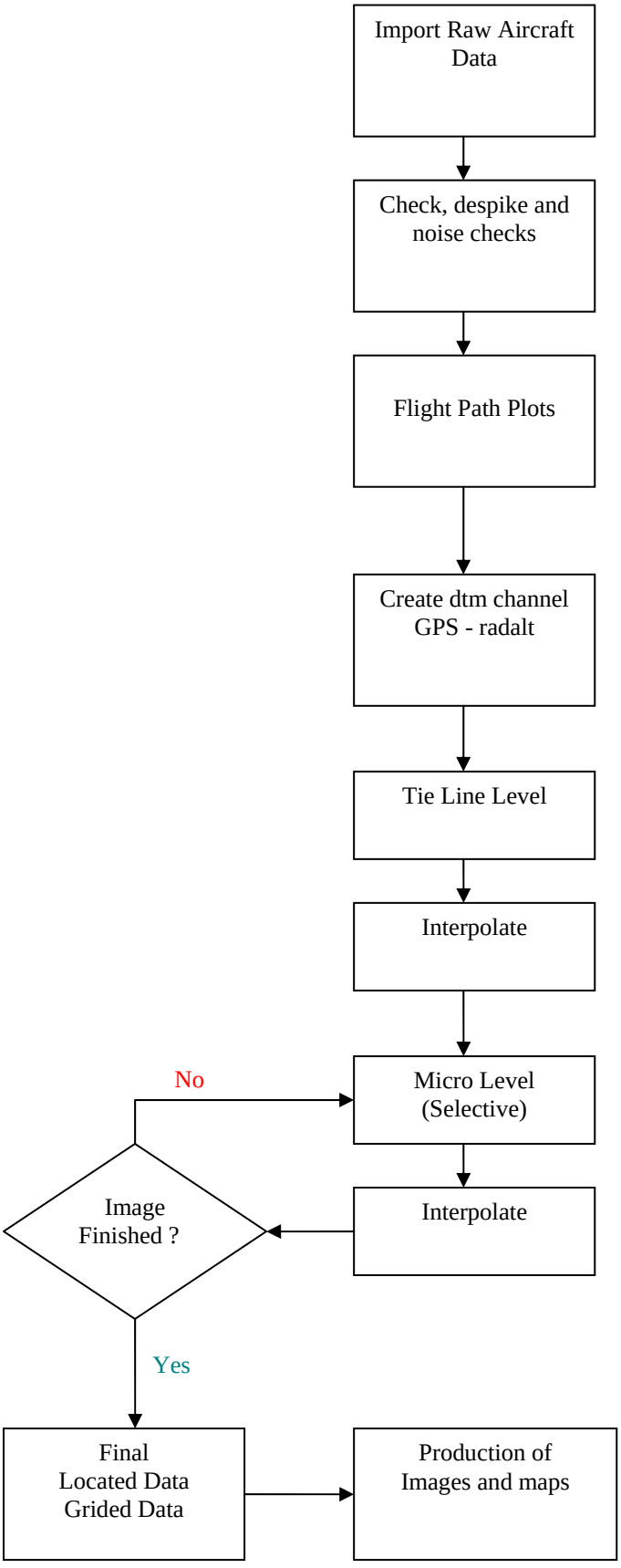

7. Magnetic Data Processing Flow Chart



8. Elevation Data Processing Flow Chart



9. Radiometric Processing Flow Chart