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This memo summarises the processing steps undertaken on gravity data recently acquired over the Waterloo project. Interpretation of these data will be covered by a separate report.

The data were acquired by Atlas Geophysics in July and August of 2015 and tied to the GA reference station at Kununurra airport.

Data received for processing consisted of 7398 stations including 353 repeat readings (includes daily base ties). The data were collected on a grid with a nominal station spacing of 1 km x 1km with infill in places to 500m x 500m.

Station postings showing the location of the survey relative to previous work are shown in Figure 1. The small holes in coverage are aboriginal heritage sites which were excluded from the survey.

The survey was merged with detailed gravity acquired around Stockade creek and the extensions of the Blackfellow Creek Fault, by Proto Resources in 2011 (P2011016) and available through the NTGS open file repository, to produce a data set of 7934 stations. The regional GA coverage consisted of the regular 12km grid and some 400m detail along the Duncan Highway. Much of the 12km grid was acquired using barometers for measuring heights and although only a small number of the regional stations appeared to be in error there were so few relative to the new survey that all the 12km stations within the survey area were excised from the GA dataset prior to merging with the more detailed data. This resulted in a final gravity data set of 9540 stations, covering an area with a 100km selvage around the tenements to allow for a good regional estimation.

The processing sequence used was as follows;
1. Load the CSV files from the contractor into a standard ExploreGeo gravity database using the Ellipsoidal height as the station height. A constant is removed from the observed gravity in order to retain precision whilst working with 4 byte real values. The constant removed is user selectable but the value used here was 9750000 µm/s².
2. Assign a unique survey number to the survey in order to enable it to be identified in the merged dataset.
3. Compute Free Air and Bouguer corrected gravity. This is computed using a second order formula from Heiskanen and Moritz (1969) with constants for a GRS80 geoid.

\[ FA = \left(2\frac{G_e}{a}\right)(1+f+m+((5/2)m-3f)\sin^2\varphi)h + (3\frac{G_e h^2}{a^2}) \]

where \( a \) = semimajor axis of the ellipsoid
\( f \) = flattening of the ellipsoid
\( G_e \) = Normal gravity at the equator
\( \varphi \) = latitude
\( m = \tilde{\omega}^2 a^2 b/GM \), \( b \) = semiminor axis,
\( \tilde{\omega} \) = angular velocity
\( GM \) = geocentric gravitational constant

The Bouguer gravity is then computed for 10 densities using the Bullard B correction for a spherical cap of radius 166.735 km

\[ B_g = 2\pi G_e \left( h + \left( \mu h - \chi R \right) \right) \]

where \( \mu = (1/3) \eta^2 - \eta \)
\( \eta = h/R \), \( R = R_0 + h \), \( R_0 = \) Radius of earth to datum
\( \chi = 1/3\left( (d + f_b \delta + \delta^2) + ((f_b - \delta)^2 + k_b) + p + m_b \log(n/f_b - \delta + \sqrt{(f_b - \delta)^2 + k_b}) \right) \)

where \( d = 3 \cos^2\alpha - 2 \), \( \alpha = S/R_0 \), \( S = \) Bullard B surface radius
\( f_b = \cos \alpha \), \( \delta = R_0 / R \), \( k_b = \sin^2 \alpha \), \( p = -6 \cos^2 \alpha \sin(\alpha/2) + 4 \sin^3(\alpha/2) \)
\( m_b = -3 \sin^2 \alpha \cos \alpha \), \( n = 2(\sin(\alpha/2) - \sin^2(\alpha/2)) \)

The Theoretical Gravity is computed using Somigliana’s formula and a GRS80 geoid

\[ \lambda = G_e \left( 1 + k \sin^2 \varphi \right) / \left( \sqrt{1 - (e^2 \sin^2 \varphi)} \right) \]

where \( k = b^2 G_p / (a^2 G_e) - 1 \)
\( e = \sqrt{((a^2-b^2)/a^2)} \)

Finally the atmospheric correction is applied to account for the weight of air

\[ \delta_{g\text{atm}} = 87.4 - 0.0099h + 0.000000356h^2 \]

A more thorough review of and background to, these formulae are given in;

LaFehr T. 1991. An exact solution for the gravity curvature (Bullard B) correction. Geophysics 56, pp1179 -1184


Recommended Standards and Format for the North American Gravity Database 2003

4. Check the new data for repeat readings closer together than 2m. A value of 2m rather than something smaller is used because the database uses 4 byte reals which result in 7 digits of precision. UTM Northings are therefore rounded to the nearest metre and Eastings to the nearest decimetre. A value of 2m captures any rounding errors when comparing positions. The statistics of the repeat readings are reported to the log file and inspected for differences in elevation and observed gravity.

The new data are then merged with any other detailed data which exists and again checked for repeats, this time to compare any tie stations between the new data and previous surveys.

6. The combined detail datasets are then merged with the regional Geoscience Australia
gravity data and again a search is made for repeat readings to evaluate the quality of any ties to the national database.

7. Because of clear terrain effects in the data a terrain correction was computed using an elevation model made up of the SRTM30 heights, adjusted to the ellipsoid merged with the gravity heights for an area 100km larger than the gravity dataset. A number of densities are computed and compared with elevations to select one which shows a reasonable decorrelation between topography and terrain corrected Bouguer gravity. The process assumes that topography and density are not related which is often a false assumption. The final choice of reduction density is thus subjective and may vary, depending on the density of the rocks in area of interest and target sought.

8. Finally the merged gravity data are iteratively gridded using the limits of the new data and a grid cell size appropriate for these data. A 1st vertical derivative is computed of this grid in order to highlight problems in the data.

102 stations were repeated within this survey with the repeats generally being good. There were however 31 stations with repeat Free Air Gravity mismatches of 0.5 to 1 \( \mu m/s^2 \) and 13 stations with mismatches of 1 to 1.57 \( \mu m/s^2 \). Elevation errors were all less than 0.3m. Given the coarse scale of the survey these errors are acceptable and are thought to stem from excess vibration from the helicopter rotors. The reading is taken close to the helicopter with the station position fixed by a GPS receiver on the tail boom of the chopper. With selective throttle control the pilot can reduce rotor vibration to the point where a self levelling meter can acquire repeatable data. The worst mismatches were early in the job, reflecting a learning process by the pilot with regard to revs.

Other than the tie to the Kununurra airport station there were no common stations between this survey, the Proto 2011 survey and the GA national database. The merged dataset gridded well indicating no major levelling issues in the three data sets. Several small hills correlated with noticeable lows in the bouguer gravity so a terrain correction was undertaken. A terrain corrected bouguer density of 2.5 \( T/m^3 \) was selected as the best density for this area. The terrain corrected grid showed quite a marked smoothing relative to the Bouguer Gravity in areas of rough topography.
Figure 1: Station posting overlain on Auslig 250k map. This survey - red, GA national database - black, Proto Resources open file - magenta