Environment Waikato Technical Report 2008/17

Estimation of Groundwater Bore Elevation Using a Digital Elevation Model

www.ew.govt.nz
ISSN 1172-4005 (Print)
ISSN 1177-9284 (Online)

Environment Waikato
REGIONAL COUNCIL

Prepared by:
Bevan Jenkins

For:
Environment Waikato
PO Box 4010
HAMILTON EAST

10 January 2008

Document #: 1211847

Peer reviewed by:
Bill Vant Date November 2008

Approved for release by:
Viv Smith Date November 2008

Disclaimer

This technical report has been prepared for the use of Waikato Regional Council as a reference document and as such does not constitute Council's policy.

Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

While Waikato Regional Council has exercised all reasonable skill and care in controlling the contents of this report, Council accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Acknowledgement

Thanks to Ed Brown and Bill Vant for their comments on this report.

Table of contents

List of figures

List of tables

Executive summary

The elevation of groundwater bores within the Waikato region was required by Environment Waikato (EW) for entry into groundwater analysis software (Hydrogeo Analyst). As of October 2007, there were 11600 groundwater bores in EW's database (LOCATED). Of these only 1734 had an elevation assigned to their location, leaving 9866 bores with an unknown elevation.

A Digital Elevation Model (DEM) was used to estimate the elevation for all bore locations. These estimates were then verified against the 'known' elevations that existed in LOCATED. A very strong relationship was found, with 96.8% or 1679 of 1734 estimated elevations within 20 metres of the measured elevations. However, there existed individual cases where the DEM estimate was markedly different to the LOCATED value.

Further investigation was carried out on sites that had an absolute difference between the two methods of greater than 20 metres. This was achieved by use of a Geographic Information System (GIS), which was used to overlay the sites in question and the relevant NZMS 260 topographic map. In all cases it was found that the topographic maps agreed with the DEM values rather than the LOCATED elevations. Thus, an additional advantage of the methodology is the illustration of errors that exist in the current database.

The comparison analysis was repeated with the estimated values from the topographic maps being substituted for the outliers (absolute residual greater than 20 metres). The replacement of these outliers led to an even stronger relationship, with 99.9% or 1733 of 1734 estimated elevations being within 20 metres of the measured elevations.

The methodology presented has application to be used for all locations that require an elevation within the Waikato region, as long as the uncertainties associated with the produced values are acceptable. The methodology is not intended to replace more accurate methods such as direct surveying or Global Positioning System (GPS) when the situation and resources dictate.

1 Introduction

The elevation for all groundwater bores in Environment Waikato's (EW) database (LOCATED) was required for entry into a new database and analysis software (Hydrogeo Analyst). The elevation is required by Hydrogeo Analyst to position the bores in analysis such as lithological cross sections or in the production of three dimensional plots of the bores, land surface and geology.

A number of methods exist for the measurement of elevation including surveying to a known datum or use of Global Positioning System (GPS). Elevation can also be estimated from topographical maps such as the NZMS 260 series. However, in the case of the groundwater bores these methods would have been logistically time consuming or expensive due to the number of locations involved. In October 2007, there were 11600 bores in LOCATED, of which only 1734 had an elevation listed, leaving 9866 bores with elevation unknown.

A decision was made to use a Digital Elevation Model (DEM) to estimate the elevations for the bores without elevations in LOCATED.

This method is not intended to replace the use of more accurate methods such as the use of GPS or direct surveying, but rather to provide a first estimation of elevations for bores within the Waikato region for use within Hydrogeo Analyst. These elevations will be used in analysis such as the assessment of the geology, which would otherwise be unavailable. These methods will still be used in situations where the time and/or expense associated with the greater accuracy can be justified.

2 Methodology

2.1 Estimation of elevation

A digital elevation model (DEM) was used to estimate elevations for all bores in Environment Waikato's database. The DEM has a horizontal accuracy of +/- 3.0 metres and a vertical accuracy of +/- 6.0 metres at 90% confidence. The grid has a 20 metre by 20 metre resolution (Environment Waikato 2004).

All bores in the LOCATED database on 11 October 2007 were queried to obtain a unique identifier (Located key) and their location. The easting and northing coordinates were rounded to the nearest 20 metres, to align them with the DEM grid. The DEM was queried via a visual basic script to return an unrounded elevation for each bore.

2.2 Verification of accuracy

To verify the accuracy of the method, all bore elevations that existed in LOCATED database were queried and these elevations were compared with the values obtained from the DEM to verify the process.

Sites that had greater than 20 metres of difference in the elevations provided by the two methods were further investigated by use of a GIS to overlay the locations and relevant NZMS 260 topographic maps. The contour lines immediately up gradient and down gradient of the site were recorded as this provides a definite limit to the elevation. In addition a 'best estimate' of the actual elevation was made from the topographic maps. The estimate was made to the nearest 5 metres based on the location of the bore in relation to the surrounding contours.

3 Results

3.1 Estimation of elevation

A total of 11600 bores existed in the database at the time of the query (11th October 2007). Elevation was able to be estimated for 11594 bores from the DEM, while the remaining 6 bores had a spatial location outside that of the DEM. Elevations already existed in LOCATED for 1734 bores. The different measurement methods used for the existing LOCATED elevations is shown in Table 1. The majority of bores in the database had elevations for which the method of measurement/estimation was 'unknown'.

Table 1: Summary of elevation measurements used for bores in LOCATED

Altitude locator method	Count	Spatial Accuracy (m)
Geodetic datum survey	282	0.01
High order GPS survey	37	0.01
Low order GPS survey (10 m)	2	10
Low order GPS survey (5 m)	20	5
Read from 25000 - 10001 scale source	3	25
Read from 50000 - 25001 scale source	3	50
Unknown	1387	-

3.2 Verification of accuracy

There was a very strong relationship between the estimated elevation from the DEM and the existing LOCATED values (Figure 1). In term of differences, 1679 (see Table 2) of 1734 sites or 96.8% had DEM elevations that were within 20 metres of the LOCATED values. However, there were a number of sites that exhibited relatively large residuals Figure 2 and Figure 3). Fifty eight[1] sites had a difference of greater than 20 metres between the DEM and LOCATED elevation (Table 2). While twenty two sites had residuals greater than 50 metres.

There does not appear to be a strong relationship between the magnitude of the residuals and the DEM elevation (Figure 3). However, when the residuals were plotted spatially it was found that 21 of the 22 sites with residuals greater than 50 metres were contained within the Northern Taupo and Reporoa area.

Replacing the values in LOCATED which had a residual greater than 20 metres with estimates from the NZMS 260 topographic maps led to a strengthening of the relationship between LOCATED and DEM (Figure 1).

The elevation values estimated from the NZMS 260 topographic maps in all cases resulted in a reduction in the residuals (Figure 2). Of the 58 cases, there was one residual of 25 metres, one of 15 metres, and all the rest (n = 56) resulted in residuals of 10 metres or less.

Using the elevation estimations from the topographic maps, 1733 (see Table 2) of 1734 sites or 99.9% had DEM elevations that were within 20 metres of the LOCATED values. While 1620 of 1734 bores or 93.4% had absolute residuals of 10 metres or less.

The absolute residuals of the modified LOCATED values and DEM elevation is plotted against the DEM elevation in Figure 3.

[1] Three of these were immediately dismissed as outliers as their elevation was listed in LOCATED as greater than three thousand metres. It is likely that these errors occurred during data entry as the DEM value was 366 metres, while the LOCATED elevation was 3676 metres.

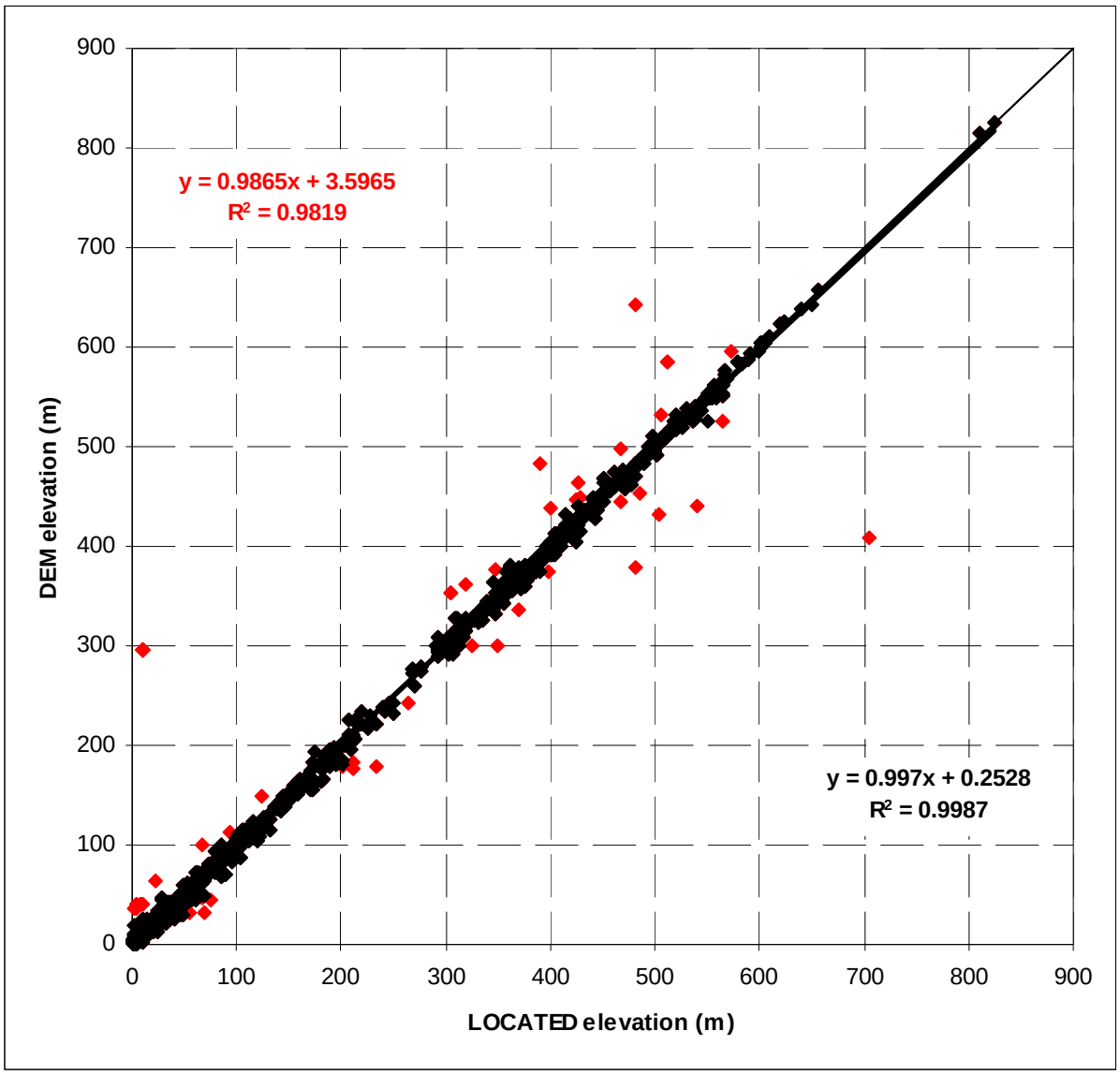

Figure 1: **Estimated elevation from the DEM and elevation as found in LOCATED.** Outliers (absolute residual greater than 20 metres) are in red and relationship after outliers were replaced by topographic estimates is in black.

Table 2: **Counts and cumulative percentages for the absolute residuals 'pre' and 'post' replacement of the 'outliers' by topographic map estimates.**

Absolute residuals - bins	Pre topographic estimation		Post topographic estimation	
	Count	Cumulative percent	Count	Cumulative percent
0	1	0.1	1	0.1
0.5	232	13.4	238	13.8
1	231	26.8	238	27.5
2	368	48.0	370	48.8
5	505	77.1	526	79.2
10	236	90.7	247	93.4
20	106	96.8	113	99.9
50	36	98.9	1	100.0
100	6	99.3	0	100.0
300	13	100.0	0	100.0

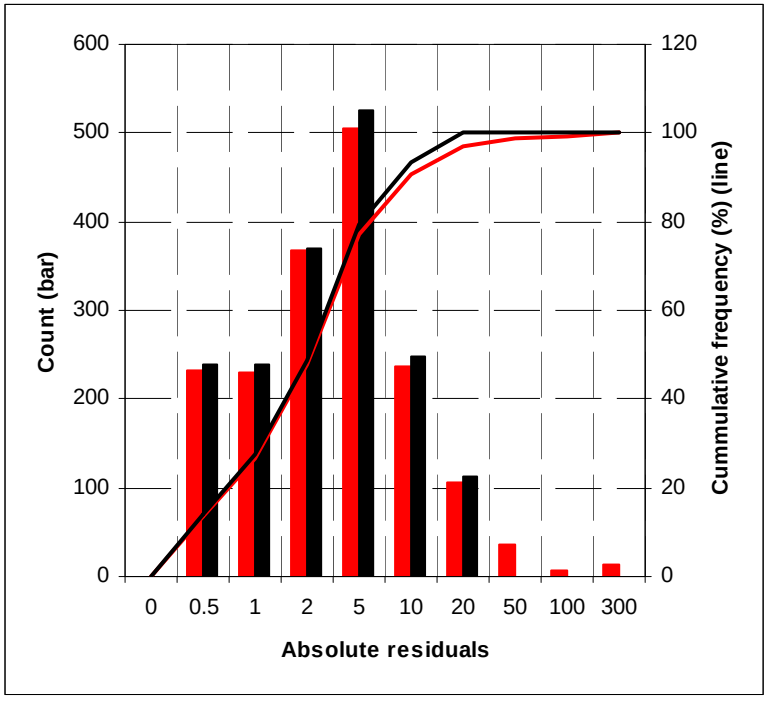

Figure 2: **Absolute residuals between DEM and LOCATED elevations.** **Initial values (red) and values after outliers replaced with estimates from topographic maps (black). The cumulative frequency is plotted as a line on the secondary axis.**

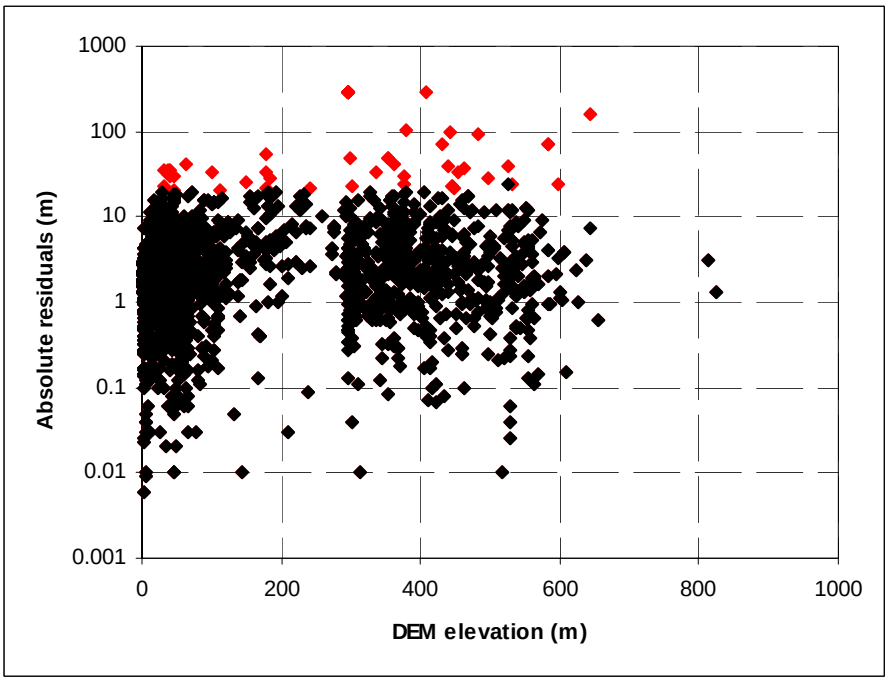

Figure 3: **Absolute residuals (log scale) against the DEM elevation.** **Initial values (red) and values after outliers replaced with estimates from topographic maps (black).**

4 Discussion

The initial relationship between the estimated values from the DEM and known values from located was very strong. However, there were a number of sites that had a relatively large difference between the two values. When sites with greater than 20 metres of difference were investigated, it was found that in all cases that the topographic map value had a better agreement with the DEM elevation that the LOCATED value.

The replacing of the 'outliers' in LOCATED with estimates from the NZMS 260 topographic series resulted in a stronger relationship between the DEM and LOCATED elevations. The aim of this study was to compare the DEM estimates with existing LOCATED values in an attempt to determine whether the DEM estimation method was suitable for obtaining elevations. During this exercise, when a large difference in elevations from the two methods was found, the NZMS 260 topographic series was used as a further check. It must be noted that the there is a degree of inaccuracy inherent in the NZMS 260 maps.

In addition the methodology has provided a useful quality assurance of the data in the LOCATED database. The spatial distribution of the sites with absolute residuals greater than 50 metres indicates a systematic error as all but one of the sites (n = 22) occur in the North Taupo and Reporoa areas. It appears that many of these values were collected at the same time as the site numbers are sequential. This may indicate that they were collected on a small number of sampling trips with incorrect GPS setting. Further investigation into the dates that these values were entered into the database is warranted.

The elevation for sites that have a residual of less that the arbitrary value of 20 metres may also be incorrect. However, this can not be verified against the NZMS 260 topographic series as the contour interval is 20 metres and additionally, this is getting near the stated accuracy of the DEM of +/- 6 metres.

The methodology employed relies on the easting and northing location information to estimate the elevation. In most case with the verification data, this will have been collected at the same time as measured elevation measurements. The methods used in the collection of elevations will also result in more accurate easting and northing measurements. However, for the sites without elevation data, the location coordinates have been collected in a variety of ways, with a wide variety of accuracy. This study has shown that given a set of coordinates it is relatively easy to determine the elevation at that location (with the inherent inaccuracies already mentioned). Nevertheless, the caveat must be made that if the starting coordinates are wrong then the returned elevation value will be meaningless.

Improvements to the methodology for estimating the DEM elevation could be made. Currently, the bore easting and northing is rounded to the nearest 20 metres to align it to the DEM. That is the nearest neighbouring DEM value is used as the bore elevation. Instead the surrounding DEM values could be used to interpolate a DEM at the exact bore location. This would make the calculation slower and there may be little point in doing this for locations that have greater than 10 metres uncertainty in their easting and northing.

LiDAR (Light Detection and Ranging) data, which is available for limited areas of the region at present could be substituted for the DEM. However, the issues that exist around the uncertainty in the easting and northings of the sites would negate some of the gains on accuracy of the elevations.

A method for the estimation of bore elevations for inclusion in the software package Hydrogeo Analyst has been presented. The elevation estimates obtained have shown a strong relationship with measured values.

References

Environment Waikato. 2004: METADATA_1207.00@EW.GOVT.NZ_Digital Elevation Model (DEM) – 20M. Doc # 900127, Environment Waikato, Hamilton.