Digital v Manual Volumetric Calculations for Mineral Resources

A brief comparison of accuracy

Introduction

High quality and accurate calculation of material volumes is central to the work of geologists in the minerals industry and is fundamental to the operation of soundly designed economically robust mines and quarries. At the exploration stage the mineral resources and reserves need to be determined as accurately as possible but so do the volumes of all the other materials. Soils, overburden, waste rock, silt or tailings, available voids or storage areas are all essential components of integrated life of mine quarry designs with deliverable restoration schemes.

The author has published 2 papers in the Quarterly Journal of Engineering Geology and Hydrology (in 1999 and 2012) on the accuracy of sand and gravel reserve calculations, demonstrating that high standards of accuracy can be achieved and are achieved in the majority of cases. The aim of this article is to report on a limited comparison of results obtained from manual methods of calculation and digital techniques.

Over the course of a 40 year career the geologist's toolbox has moved on from manual processes using paper plans, planimeters and simple calculators to purely digital plans derived from sophisticated field surveys and computer modelling of mines, pits, quarries and engineering structures. During the transition years it was possible to record a number of mineral prospects that had been assessed by both means although insufficient examples are available to publish a statistically robust comparison suitable for a peer reviewed publication or conference proceedings.

Volume calculation

Whether mineral and other material volumes are calculated by digital means or manual methods it is good practice to perform a simple order of magnitude check on the numbers. A "quick and dirty" estimate helps to prevent some simple human error such as mis-reading a scale or a computer input typing error from having a major effect on the numerical result.

Such a rough estimate might be as simple as estimating the surface area of a site taking it as an approximate rectangle or an approximate circle, multiplying that by the intended depth of excavation, and reducing that volume by a factor to allow for pit edge standoffs, haul roads and benching geometry. Typical reducing factors in an aggregate quarry might be a 15% reduction of surface area (from the boundaries) and a 15% reduction per bench level downwards. Or even just a simple 30% reduction on the overall cube or cylindrical volume.

Any calculation method is only as good as the quality of input data typically derived in a mineral prospect from field mapping, exploration boreholes, aerial imagery, plans, surface surveys, and non-invasive information from various geophysical techniques. Geological judgement then has to be applied to the raw data in order to control how a computer model deals with features such as changes in mineral layer thickness between adjacent boreholes, extremely irregular geological interfaces, clustering of data due to irregular borehole spacing, edge effects where a proposed pit edge runs between boreholes or edge effects where there is no hard data available on the outside of the proposed pit limit.

It is all too easy to place over-reliance on computer models and it does no harm to remember that digital and manual models alike are still subject to the laws of mathematics and the quality of original information.

During the 1980s and 1990s when the use of quarry modelling software packages and digital land survey equipment was becoming the norm there was an opportunity in the author's then company to assess aggregate site prospects in the traditional way and compare the results with computer derived numbers. This cautious process allowed a confidence to grow in the computer models and the means of using them whilst meeting the corporate governance obligations of a company geologist. (Wardrop 2008)

The sites

As with the QJEGH papers on comparing sand and gravel reserves with calculations there are relatively few sites out of all the exploration prospects that are suitable for using in the comparison in this article. In essence each site must have been fully drilled by exploration boreholes to the satisfaction of the geologist, have the benefit of a digital land survey, and a suitably robust quarry pit design that could be modelled both manually and digitally. In the author’s company there was a degree of independence imparted by the fact that manual calculations would be done by the geology department whilst electronic models were developed by the land survey team.

Most of the twenty four prospect sites used here are sand and gravel prospects in a variety of geological settings and most are a straightforward comparison of mineral volume numbers. One excavation in rock is included and 3 sites are located in ‘solid geology’ by way of the Folkestone Beds sand deposits. The dataset could legitimately be doubled by also comparing overburden volumes for each site but that information is no longer available.

One complex sand and gravel site offered an opportunity to compare 2 different software packages and also 2 different algorithms in one of the packages. In the latter example the mineral layer was calculated by a comparison of it’s upper and lower surfaces, and again by subtraction after comparison of both surfaces with a common datum.

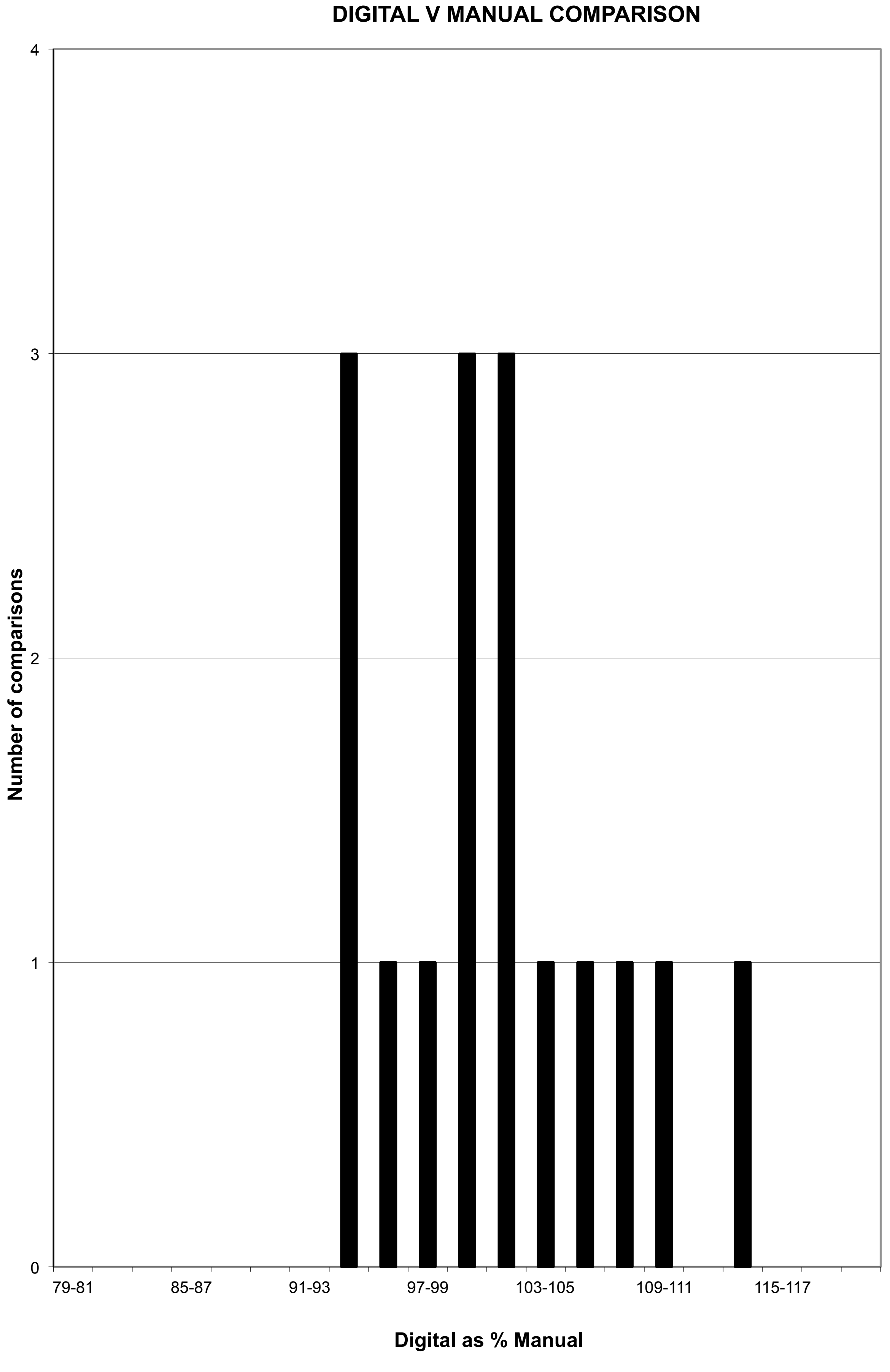
Sites must remain anonymous for reasons of commercial confidentiality. Ten of the prospect sites are in operation.

Manual v Digital Reserve Comparisons

Site	Site Geology	Year	Reserves Volume: Manual	Reserves Volume: Digital	Digital as % Manual	Precision
Alpha	Quaternary gravel over Triassic Mudstone	2005	3,909,906	3,962,047	101.33	1.33
Bravo	Terrace gravels over Mercia Mudstone	2010	873,187	904,150	103.55	3.55
Charlie	Magnesian Limestone	2010	2,575,000	2,600,000	100.97	0.97
Delta	Folkstone Beds	2008	2,313,315	2,629,970	113.69	13.69
Echo	Thames Terrace over London Clay	2006	796,343	752,730	94.52	- 5.48
Foxtrot	Glacial gravels over Lias Clay	2008	3,580,529	3,575,904	99.87	- 0.13
Golf	Fluvioglacial gravels over Chalk	2002	3,899,200	4,219,712	108.22	8.22
Hotel	Folkstone Beds	2005	2,569,177	2,806,817	109.25	9.25
India	Folkstone Beds	2004	8,618,750	8,286,016	96.14	- 3.86
Juliet	Avon valley gravels over Bracklesham Beds	2005	11,872,984	11,762,638	99.07	- 0.93
Kilo	River gravels over Poole Formation	2001	4,822,500	4,518,405	93.69	- 6.31
Lima	Glacial gravels over Chalk	2006	15,781,777	16,214,674	102.74	2.74
Mike	Glacial gravels over Chalk	2004	4,192,814	4,147,439	98.92	- 1.08
November	Fluvioglacial gravels over Mercia Mudstone	2006	862,943	916,640	106.22	6.22
Oscar	Glacial gravels over Chalk	1991	5,783,808	5,735,819	99.17	- 0.83
Papa	Glacial gravels over Chalk	1984	1,025,708	1,075,826	104.89	4.89
Quebec	Terrace gravels over Chalk	1989	2,411,220	2,262,390	93.83	- 6.17
Romeo	Terrace gravels over Ampthill Clay	2011	2,486,379	2,517,138	101.24	1.24
Sierra	River gravel over Mercia Mudstone.	1996	2,987,116	3,140,000	105.12	5.12
Tango	Thames Terrace over London Clay	2003	9,387,714	9,489,237	101.08	1.08
		Total	**90,750,370**	**91,517,552**	**100.85**	**OVERALL**
					101.68	**MEAN**
					101.48	**MEDIAN**

	DIFFERENCE BETWEEN SOFTWARES		**Package A**	**Package B**		
Uniform	Glacial gravels over Chalk	1991	5,801,419	6,582,136	113.46	
Victor	Glacial gravels over Chalk	1991	17,718,150	16,628,862	93.85	
					103.65	**MEAN**

	DIFFERENCE BETWEEN METHODS		Surfaces	Datum	Datum as % Surfaces	
Whisky	Glacial gravels over Chalk	1991	4,399,520	4,276,171	97.20	
Xray	Glacial gravels over Chalk	1991	12,173,320	12,462,300	102.37	
					99.79	**MEAN**


DIGITAL V MANUAL COMPARISON
Number of comparisons
0
1
2
3
4
79-81
85-87
91-93
97-99
103-105
109-111
115-117
Digital as % Manual

Results

Reserve evaluations

The numerical results are presented in the table above and include reserve calculations from exploration sites totalling over 90 million Tonnes. Each of the 20 mineral sites is listed with the reserve calculation derived by manual and digital procedures. Each is a like for like comparison based on the same quarry pit design.

Precisions are then generated by calculating each computer generated reserve figure as a percentage of the manually generated figure - it would be equally valid to do this comparison in reverse. It is important to remember that these figures do not reflect accuracy - as defined by how much mineral is excavated and sold from an operation compared with the reserve calculation - but the mathematical precision of alternative methods of calculation

The results show a very narrow spread from a minimum comparative figure of 93.69% to a maximum of 113.69%. This higher figure is an outlier as illustrated on the bar chart and the continuous statistical distribution of results in fact ranges from 93.69% to 109.25%. The overall net total of results, that becomes very relevant when a portfolio of sites represents an operating company landbank asset, is 100.85%.

The Mean is 101.68 and the Median is 101.48, with 12 out of 20 results being positive as in the digital offering a larger result than the manual. Over this relatively limited dataset these numbers indicate that the distribution is close to 'normal' with a slight skew towards digital computations tending towards slightly higher reserve values. These precisions however are very high by any standards and a skew of 1% or so is insignificant.

Intuitively it is perhaps not surprising that digital models display a slight tendency towards higher figures. Informal conservatisms can in some ways be more easily built into manual procedures than they can into digital ones. For instance, overburden volumes could be rounded up and mineral volumes could be rounded down (usually only in the second decimal place); a few centimetres of non-recovered mineral could be allowed on the top and bottom of the mineral layer; and occasional lenses of silt or clay within the gravel layer could be simply added to the overburden thickness. In a digital model very specific instructions have to be given to the computer model on each and every layer interface.

Bearing in mind that the QJEGH papers referred to have demonstrated the standards of accuracy that are possible one of the rules of thumb that could be applied to digital models would be a simple 1.5% reduction in the computed reserve tonnages. This could in fact be applied at the conversion factor stage where a decision is made on converting cubic metres into Tonnes.

Alternative softwares

Two results are available, in fact applying to discrete parts of a very extensive and complex site. One result of digital calculation as a percentage of manual methods gives 113.46% whilst the second result is 93.85%. The raw drilling and survey data is of the same standard for each site.

It might be reasonable to assume that the different precision and the different arithmetic sense of it is due to factors such as edge effects; how the software interprets very irregular surfaces; the relationship between topography and geology; or the spatial alignment of survey data points relative to exploration boreholes.

Different methods
Two results are also available for this analysis, also parts of the above mentioned complex site. The comparative results from modelling between layer boundaries and between a layer boundary and a datum are 97.20% and 102.37%. Such a high degree of agreement is to be expected but it is nonetheless interesting that numbers do not completely coincide and perhaps this is attributable to the variables suggested above.

Conclusions
The comforting high level conclusion is that reserve calculations carried out by either digital or manual means are, to all intents and purposes, equally precise and therefore equally accurate.

There is a very small tendency for digital models to produce slightly higher reserve figures than manual models, most probably due to the manner in which the geologist can apply the conservatism that needs to reflect the realities of physical excavation of highly variable sand and gravel deposits.

The real power of digital models is in their ability to be revised without an entire re-calculating process as one would have to do for each version of a manual calculation; their facility for 3D visual modelling, section drawing, scenario planning, mineral quality modelling, and generating options for quarry operation in a time effective manner.

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