



The Effect of Downhole Survey Uncertainty on Modelled Volume

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WHITE PAPER

Abstract

Downhole survey uncertainties observed at De Beers operations prompted further investigations. In this paper a range of survey errors was applied to the orebody model at an existing mine. Visualising the sphere of uncertainty associated with a borehole trace gives an indication of possible volume variance.

An error range of 0.1% to 10% was applied to the downhole survey data. The resulting orebody maximum and minimum volume scenarios for three different depths (200m, 500m and 800m) are presented.

For certain instruments and borehole dips, the 3D positional error can be as high as 100m at 1000m down the hole. At depths below 200m the resulting volume deviations can become significant for borehole survey errors exceeding 0.35%. At 800m depth the volume difference can approach 25%.

Introduction

In assessing the risk associated with the modelled volumes of kimberlite pipes an investigation of different downhole survey uncertainties was initiated.

External factors can influence the accuracy of a downhole survey instrument, eg. rock type, proximity and type of casing, sidewall magnetism and hole diameter. These elements were not incorporated in the different error comparisons. The deviations investigated are restricted to inherent instrument errors.

Some instruments are designed to operate optimally in an inclination range of 0 to 80 degrees; others require an accurate collar azimuth and dip to preclude continuation and accumulation of error down the hole. Empirical observations for borehole survey data from De Beers operations indicate maximum errors of about 100m at 1000m downhole (10%). This has been taken as the upper limit on expected error in this study. Some of the highaccuracy instruments used in the oil industry achieve errors of less than 0.1% (1m/1000m). This has been used as the lower error limit in this paper.

The error spheres created in Gemcom were used to inflate and deflate a Base Case solid/orebody at an existing De Beers operation. The resulting volume differences are tabled in below under RESULTS.

Method

This section describes the method used to visualise the 'error spheres' in Gemcom and the construction of the Maximum and Minimum solids.

Four error fields were inserted in the Gemcom SURVEY table. A 3D Coordinate field was also inserted which was desurveyed before creating a point extraction file.

The quoted error is normally given as metres per 1000m. This was doubled because the 'R VALUE' used in the point extraction file displays as a diameter.

For comparison purposes the following error range was used:

| | | | |
|---------|---|-------|------------------|
| 0.10 % | = | 1.0 | Metres per 1000m |
| 0.35 % | = | 3.5 | Metres per 1000m |
| 3.50 % | = | 35.0 | Metres per 1000m |
| 10.00 % | = | 100.0 | Metres per 1000m |

The above errors were calculated for different depths in the borehole SURVEY table for an existing deposit.

The survey error down a hole is cumulative. Three components contribute to the error, namely the azimuth error, dip error and depth. These are commonly not equal, resulting in an error 'ellipsoid'. For the sake of simplicity, and graphical presentation in Gemcom, an error 'sphere' is assumed.

Assuming no depth errors, an 'error disk' would be more accurate (Figure 1). Where the borehole trace approaches the orebody contact perpendicularly the minor ellipse radius would pertain. At the 'end' of the orebody the major ellipse radius would come into play. As the borehole trace approaches vertical the ellipse becomes a circle and the error effect is equal in all areas. This refinement has not been incorporated into the current study and the maximum and minimum volumes stated (Table 2) should be considered ends of the spectrum.

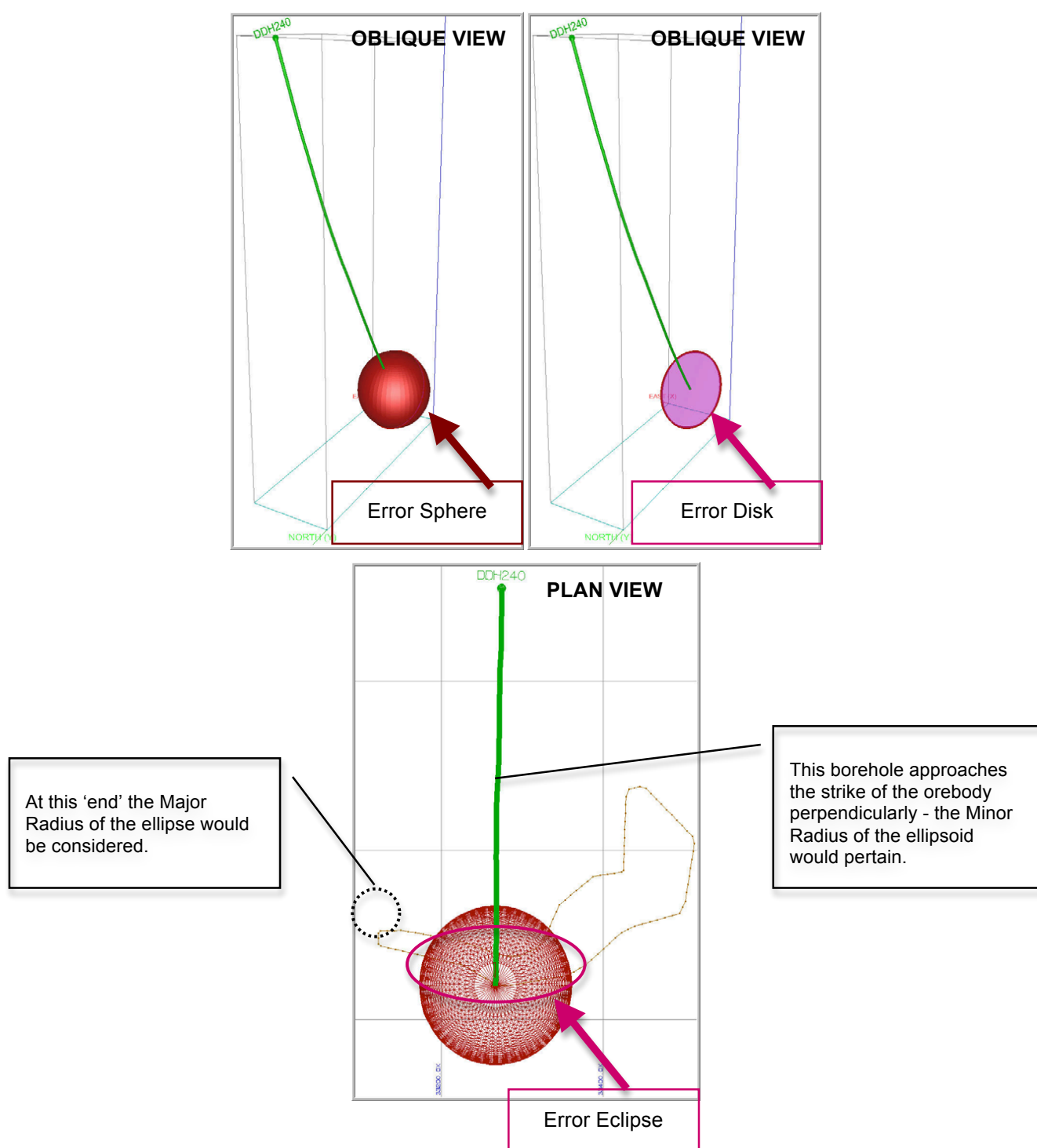


Figure 1 : Relationship between Error Sphere and the Error Ellipse - Oblique and Plan Views.

The points were inspected in the graphical environment in GEMS and average errors ascertained for relevant points in the vicinity of the Base Case model. The points are derived from a mixture of vertical and inclined holes - a greater Error Sphere (in the region of interest) will be associated with inclined holes due to their increased length. Results of this exercise are presented in Table 1.

Table 1 : Average radii for different downhole survey errors.

| DEPTH BELOW SURFACE (m) | AVERAGE ERROR RADIUS (m) | | | |
|----------------------------|--------------------------|-------|-------|-------|
| | 0.10% | 0.35% | 3.5% | 10% |
| 200 | .20 | .80 | 7.00 | 20.00 |
| 500 | .40 | 2.00 | 14.00 | 40.00 |
| 800 | .95 | 3.30 | 33.00 | 94.00 |

An overview of the error spheres associated with the error range is presented in Figure 2a, b and c.

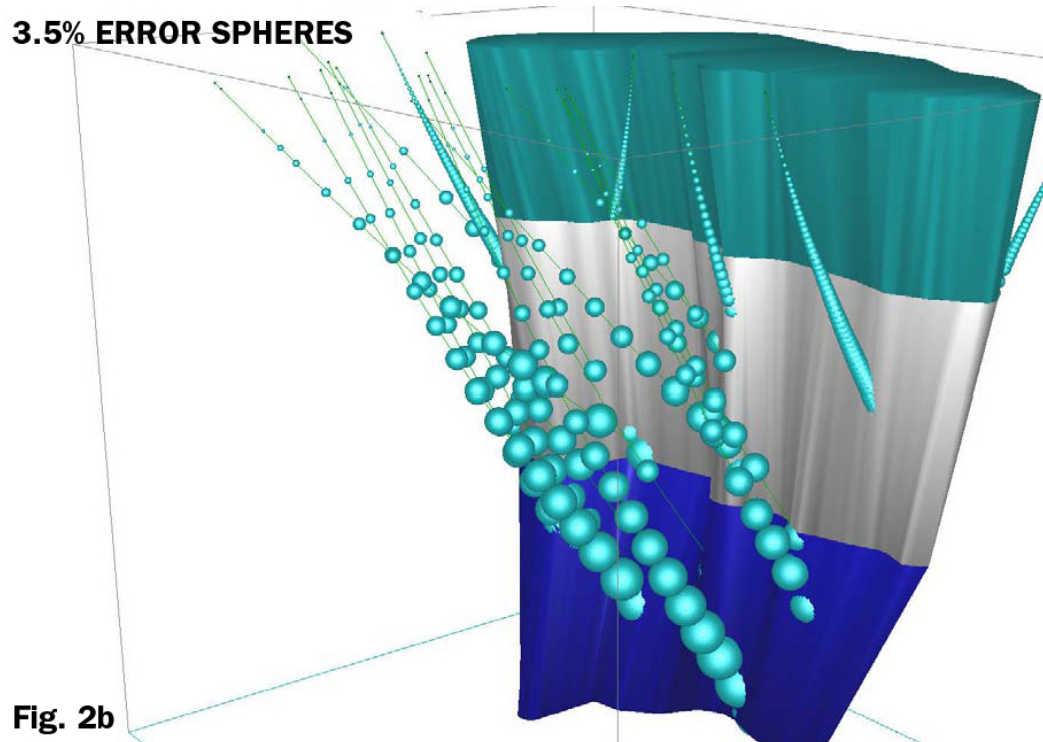
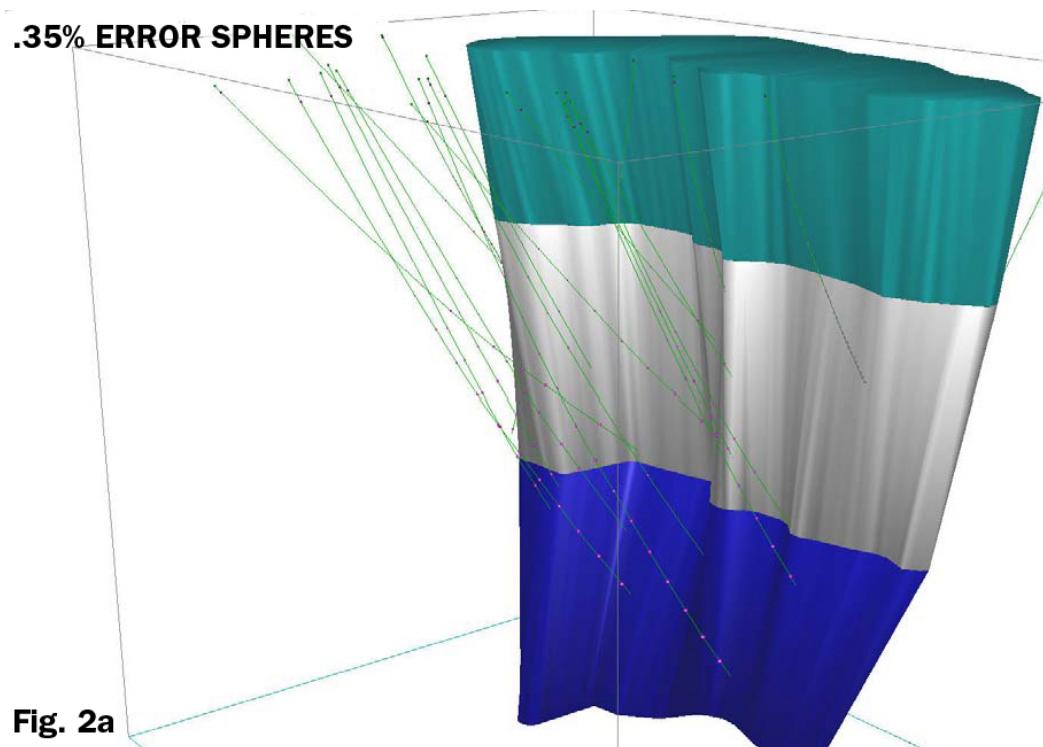
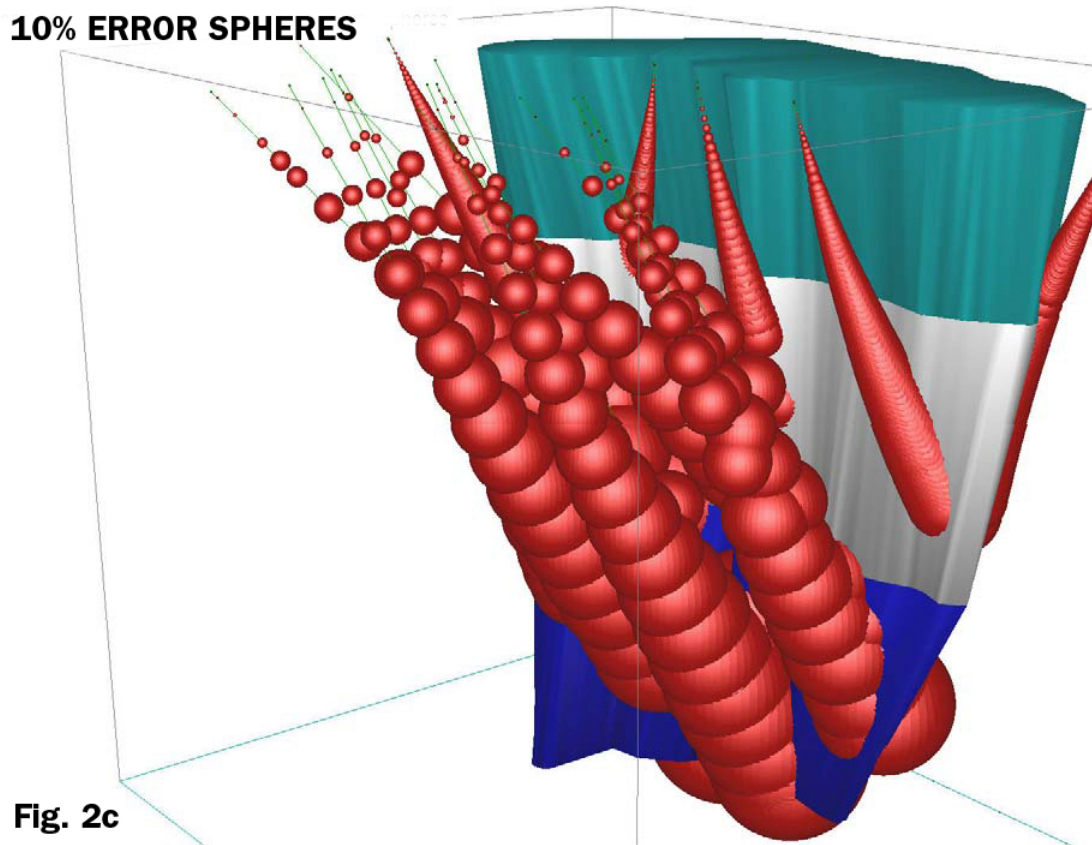


Figure 2a and 2b : Oblique overviews of the Base Case solids and the 0.35% and 3.5% error spheres respectively.



**Figure 2c : Oblique overviews of the Base Case solids for the 10% error spheres.
(The 0.1% error spheres would not show at this scale.)**

The polylines used to create the BASE CASE solid were expanded (and contracted) by the radii in Table 1, at the different levels below surface. Figure 3 illustrates these for the 3.5% error spheres. At the scale presented the Minimum, Base Case and Maximum polylines are too close together to be differentiated at shallow depths (<500m) for errors <0.35%. The error radius for the 10% scenario was too large at 800m below surface to create a Minimum polyline. The scales for Figures 2a, b and c are identical so as to compare error radii.

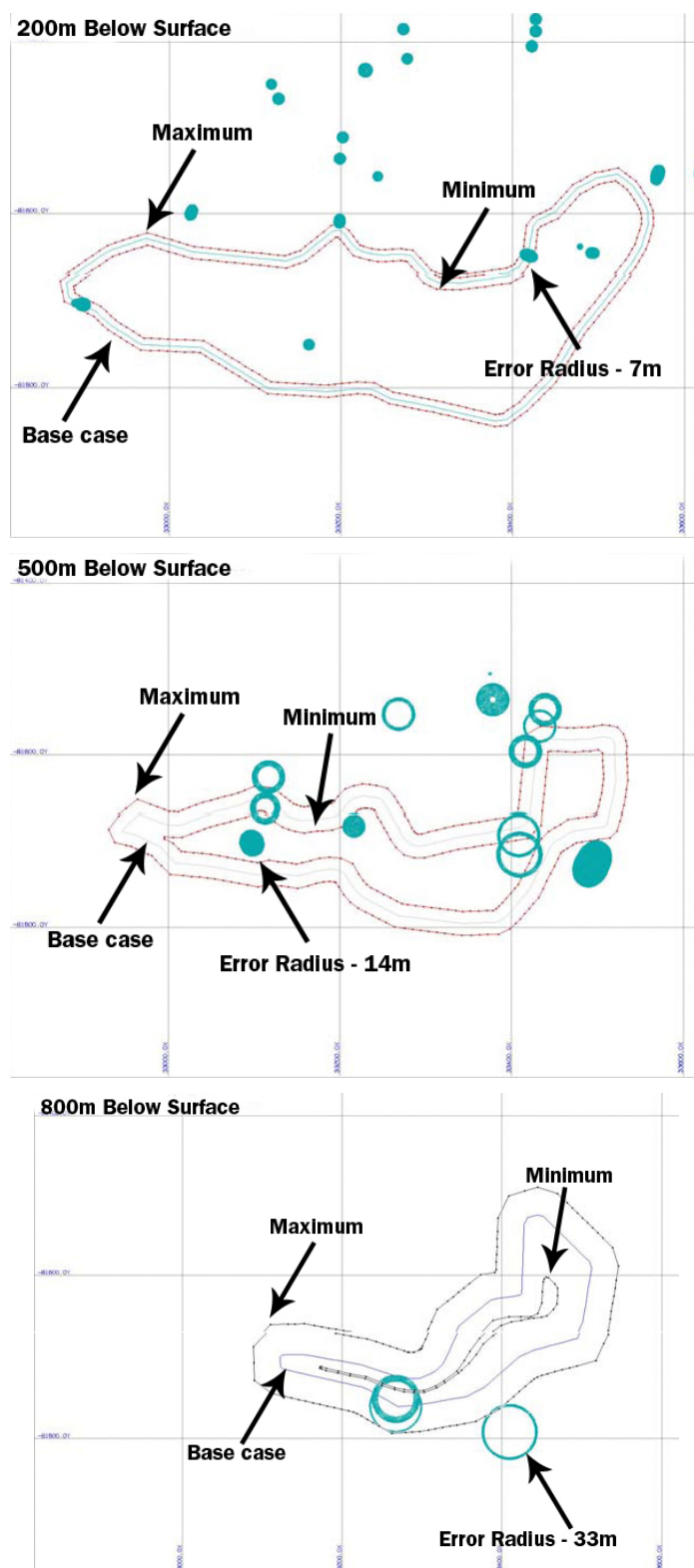


Figure 3 : Plan views of (minimum and maximum) modelling lines based on 3.5% error spheres at different depths. Plan views are at same scale.

Results

MAXIMUM and MINIMUM solids were generated using the error radii for the error range (described in Section 0). The volume differences with respect to the BASE CASE solid were determined. A MINIMUM solid was not created at 800m below surface for the 10% scenario as the error radii crossed when contracting the polyline.

A graphical representation of the above percent differences are illustrated in Figure 4:

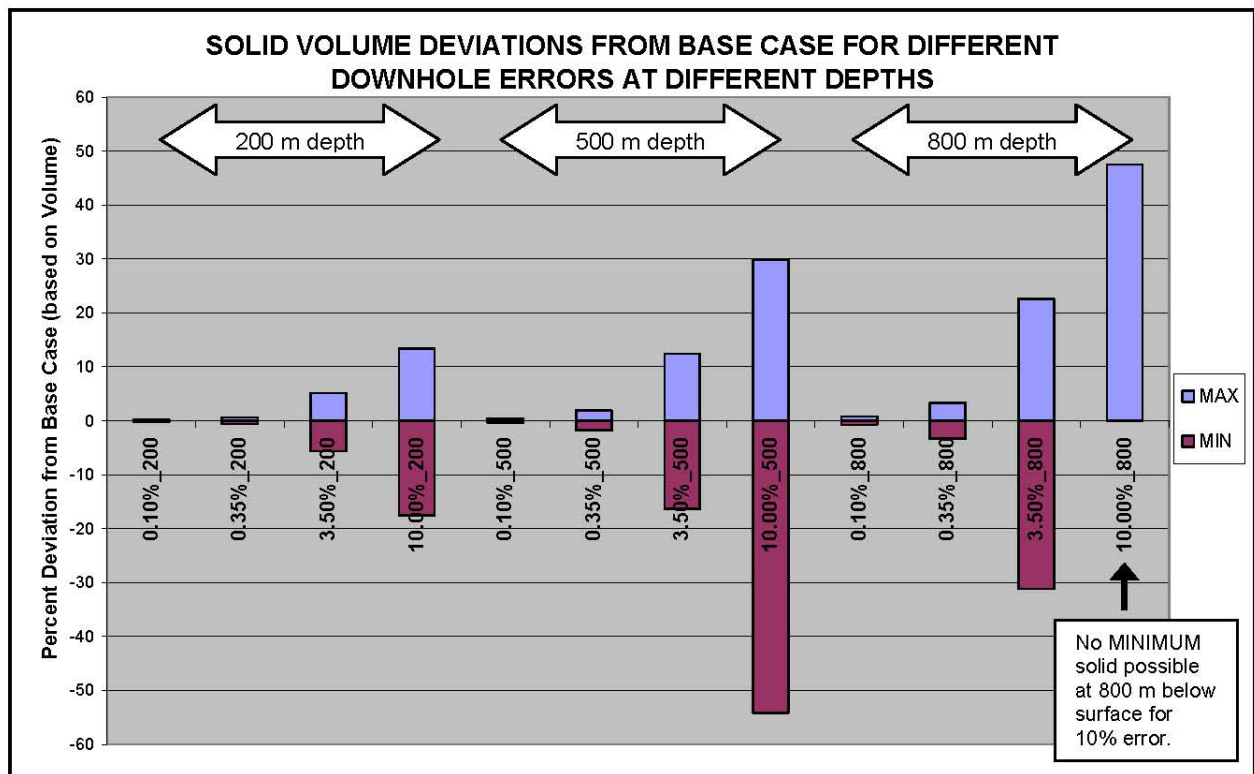


Figure 4 : Volume deviations for different downhole survey errors at different depths.

These volumetric deviations are summarised in Table 2.

Table 2: Details of volume deviations from the Base Case for different survey errors at different depths.

| ERROR PERCENT | DEPTH BELOW SURFACE (m) | SCENARIO | VOLUME (m ³) | VOLUME DIFFERENCE (m ³) | PERCENT DIFFERENCE (%) |
|---------------|-------------------------|----------|--------------------------|-------------------------------------|------------------------|
| 0.10% | 200 | MIN | 23,076,250 | -36,303 | -0.16 |
| | | BASECASE | 23,112,553 | | |
| | | MAX | 23,146,554 | 34,001 | 0.15 |
| | 500 | MIN | 43,028,766 | -166,075 | -0.39 |
| | | BASECASE | 43,194,841 | | |
| | | MAX | 43,368,102 | 173,261 | 0.4 |
| | 800 | MIN | 53,729,991 | -417,088 | -0.78 |
| | | BASECASE | 54,147,079 | | |
| | | MAX | 54,576,234 | 429,155 | 0.79 |
| 0.35% | 200 | MIN | 22,972,502 | -140,051 | -0.61 |
| | | BASECASE | 23,112,553 | | |
| | | MAX | 23,257,265 | 144,712 | 0.62 |
| | 500 | MIN | 42,468,611 | -726,230 | -1.71 |
| | | BASECASE | 43,194,841 | | |
| | | MAX | 44,025,633 | 830,792 | 1.89 |
| | 800 | MIN | 52,425,473 | -1,721,606 | -3.28 |
| | | BASECASE | 54,147,079 | | |
| | | MAX | 56,000,308 | 1,853,229 | 3.31 |
| 3.50% | 200 | MIN | 21,888,465 | -1,224,088 | -5.59 |
| | | BASECASE | 23,112,553 | | |
| | | MAX | 24,354,264 | 1,241,711 | 5.1 |
| | 500 | MIN | 37,142,962 | -6,051,879 | -16.29 |
| | | BASECASE | 43,194,841 | | |
| | | MAX | 49,324,919 | 6,130,078 | 12.43 |
| | 800 | MIN | 41,285,351 | -12,861,728 | -31.15 |
| | | BASECASE | 54,147,079 | | |
| | | MAX | 69,954,403 | 15,807,324 | 22.6 |
| 10.00% | 200 | MIN | 19,664,171 | -3,448,382 | -17.54 |
| | | BASECASE | 23,112,553 | | |
| | | MAX | 26,665,778 | 3,553,225 | 13.33 |
| | 500 | MIN | 28,026,191 | -15,168,650 | -54.12 |
| | | BASECASE | 43,194,841 | | |
| | | MAX | 61,652,966 | 18,458,125 | 29.94 |
| | 800 | MIN | Not possible | | |
| | | BASECASE | 54,147,079 | | |
| | | MAX | 103,196,607 | 49,049,528 | 47.53 |

Conclusions and Recommendations

Prior to geological modelling it is prudent to ascertain the accuracy of the downhole surveys. Visualisation of the error (eg. error spheres) may assist the modelling approach.

The magnitude of the downhole survey error generally varies with hole inclination and is cumulative with depth. The instrument used should be matched to the geological and physical environment. Some instruments are not suited to vertical holes.

For borehole survey errors exceeding 0.35% the resulting volume deviations can become significant at depths below 200m. At 800m depth the volume difference can approach 25%.

An investigation of the downhole survey error will augment any risk analysis. This aspect is pertinent to SAMREC classification. Appendix 1 in the SAMREC Code contains several references to volume risk (eg. 'Data Location').

It is suggested that a quality check be occasionally done using an instrument with the requisite accuracy ($\approx 0.1\%$). The number of check surveys will depend on the number of holes per project and depth drilled.

It is advisable to take readings while the instrument is being lowered and on extraction - a comparison of these readings will give an indication of precision.

It is common practice to snap onto boreholes when modelling geological solids/orebodies in any General Modelling Package (GMP) - the extent of the 3D error should be borne in mind when using intersections in deep inclined boreholes.

As a result of these studies De Beers is planning field tests of selected survey instruments. A pipe is being laid at a De Beers mine which will be accurately surveyed. Different instruments will be used to survey down the pipe and the results compared with the Survey Department data.

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