Local Uncertainty Benchmarking

A coal case study

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SMU -> Selective mining unit
(the smallest volume used for ore/waste delineation)

CS -> Conditional Simulations

DHSA -> Drill Hole Spacing Analysis (global)
Local uncertainty

Why is it important?

- Kriged estimate -> block scale (≈ drill hole spacing)
- But short term mining decisions based on SMU scale
- Variability, $\sigma_{\text{SMU}} \gg \sigma_{\text{Block}}$
- Penalty elements, ore specification, delivery contracts
- Need to understand local uncertainty
  -> at smaller than drill hole spacing -> at SMU scale
- Investigate shorter term uncertainty
- Integrate method into mine planning and operational decisions
At the SMU scale

Can relative uncertainty be approximated by co-kriging?
Key project objectives

#1 Investigate feasibility of using SMU kriging variances

#2 Develop and validate a relative simple methodology to
   - provide timely local uncertainties on SMUs
   - be implemented on site

#3 Use stringent benchmarking to
   - validate results
   - support and defend proposed methodology
<table>
<thead>
<tr>
<th>Methodology</th>
<th>Co-Kriging</th>
<th>Conditional co-simulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clean data set - ST and Var(_{ACC})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calculate residuals</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gaussian Anamorphorisation of data</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cross-variography</td>
<td>Cross-variography of Gaussian variables</td>
</tr>
<tr>
<td>4</td>
<td>Co-Krige ST, Var(_{ACC}) into SMUs</td>
<td>Co-simulate Gaussian variables (1000 realisations)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Back-transform to ST*, Var(_{ACC})*</td>
</tr>
<tr>
<td>5</td>
<td>Add global drift trend to each estimate</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ash* = Ash(_{ACC})* / ST*</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>St. Dev of Ash*</td>
<td>Average point values in each CS realisation into SMUs</td>
</tr>
<tr>
<td>8</td>
<td>P5, P95 ≈ Ash* ± 1.645*St Dev</td>
<td>P5, P95 extracted from simulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90% CI = [P5,P95]</td>
</tr>
</tbody>
</table>
Results

- Thickness, Fluorine, Phos closest to normally distributed
- Ash – peaked distributions (higher kurtosis)
- Sulphur – right skewed
- Benchmark uncertainty estimates will typically have 4.6% sampling uncertainty

- 90%CI

- Relative uncertainty = \( \frac{90\% \text{ CI}}{\text{estimated SMU value}} \)
## Results

Relative uncertainty for Conditional Simulations and Co-Kriging

<table>
<thead>
<tr>
<th>Variable</th>
<th>CS</th>
<th>CoK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>5.0%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Ash</td>
<td>11.8%</td>
<td>14.7%</td>
</tr>
<tr>
<td>Fluorine</td>
<td>45.6%</td>
<td>40.8%</td>
</tr>
<tr>
<td>Phos</td>
<td>35.8%</td>
<td>37.3%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>35.8%</td>
<td>37.3%</td>
</tr>
</tbody>
</table>
Results

Fluorine Q5 simulation v (Co-)Kriging

Fluorine rel. uncertainty simulation v (Co-)Kriging

Fluorine (Co-)Kriging rel. uncertainty

Fluorine simulation rel. uncertainty

Geovariances
Where no one has gone before
Results

Relative uncertainties (90% CI) by SMU

- Mean
- Max
- Min
- Current

Relative Uncertainty vs. Drillhole spacing
Conclusions

- Agreement between kriged and simulation methods is
  - Excellent for thickness
  - Very reasonable for quality variables

- CS benchmarking supports use of Co-kriging variances to estimate SMU uncertainties.

In hard rock mining using CS for local uncertainty estimates is certainly more common than in coal. However, definitely not mainstream yet. DHSA gives first pass answer so there is a potential to extend this coal, 2D case study into 3D, non coal applications. *Bearing in mind, it is only the first pass application.*
My co-authors and I wish to thank Geovariances and BHP for their support in presenting this work.

Thank you to BHP for allowing us to use data and findings from recent work undertaken at Blackwater and Peak Downs to publish this case study.