Centennial Coal

Subsidence Analysis for Underground Coal Mining Operations
The use of Airborne Laser Scanning Data

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Introduction

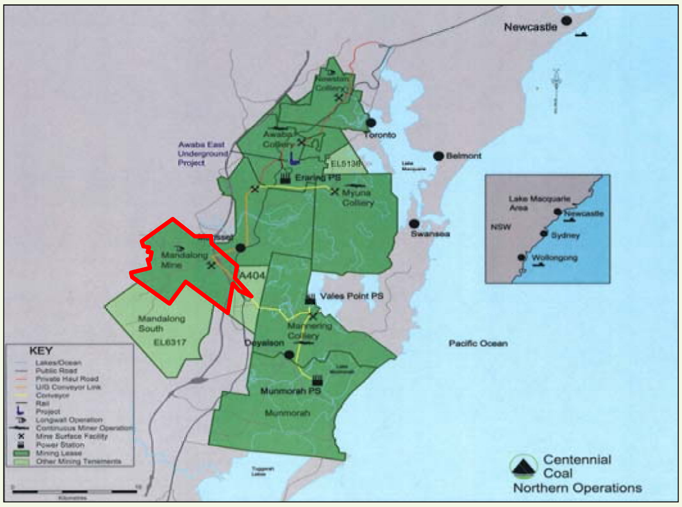
The project sought to:

- •Apply Airborne Laser Scanning (Lidar) technology to detect mine subsidence over a broad area.
- •Prove that the application was a reliable source of remotely acquired subsidence data by validating it against ground surveys.
- •Determine if the technology could complement or replace ground based methods.

Introduction

- •Mandalong - Underground coal mine
- •Centennial Coal, wholly owned Australian company.
- •Longwall extraction (void typically 160m x 3000m).
- •Produces steaming coal for domestic and export market.
- •Commenced extraction in January 2005
- •300+ employees and specialised contractors
- •24 hour – 7 day per week operation
- •Mine Designed to limit subsidence impacts

Location



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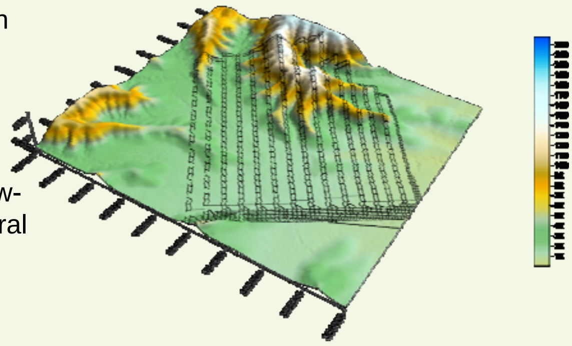
Surface Topography

•Surface elevation between approx. 10m AHD (Flood Plain) and 170m AHD (Watagan Foothills)

•The surface is used for low-intensity agriculture and rural residential retreats.

•Mining occurs between approx. -150m AHD and -240m AHD.



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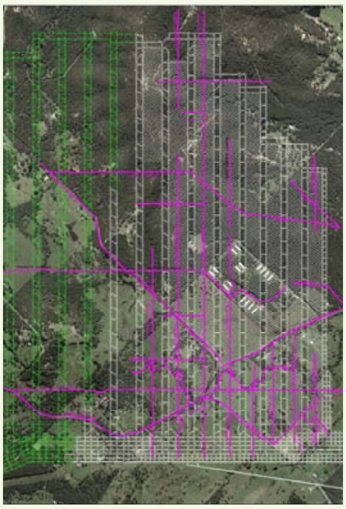
Surface Environment

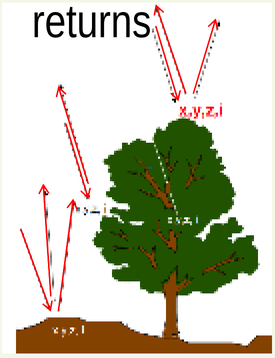


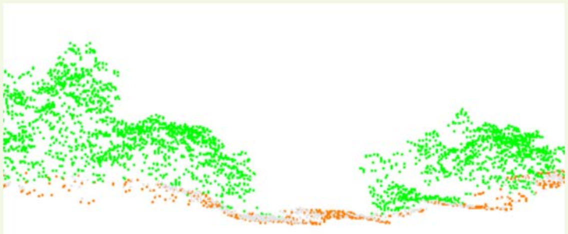
Project objective

- Bring transparency to the subsidence monitoring process along with the ability to quantitatively demonstrate the magnitude of subsidence across the whole of the mining area.
- Airborne Laser Scanning (ALS) data was originally acquired over the mining area in 2003 for the purposes of producing topographic contours.
- ALS chosen over photogrammetric methods for ALS' ability to penetrate the vegetation canopy and separate vegetation returns from ground returns ensuring that an accurate and reliable terrain model was derived.
- It was subsequently theorised that this pre-mining ALS data, together with ALS data acquired post-mining could be processed together to measure the level of vertical subsidence that had occurred across the mining area.
- Airborne Laser Scanning utilised to supplement the extensive conventional subsidence monitoring program and obtain data in areas with access difficulties and on private land that would otherwise have been without monitoring.
- Post Mining ALS data was acquired in August 2006 and June 2008

Why ALS?

- Tree penetration
- Algorithm used to filter ground and non ground returns





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ALS Acquisition

- ALS (LIDAR) data acquired by AAM using various models of Optech Airborne Laser Scanners.
- Laser strikes were classified into ‘ground’ and ‘non-ground’ by AAM, based upon algorithms tailored for the major terrain/vegetation combinations existing in the project area.
- 2003 ALS data (ground strikes only) had an estimated average point density 2.06 points per $m^{2.}$
- One hundred and eleven points were used to check the accuracy of the 2003 data, resulting in a vertical standard error of 0.040 metres for points on open clear ground.
- 2006 ALS data (ground strikes only) has a 7.81 points per m^2 estimated average point density.
- One hundred and sixty three points were used to check the accuracy of the 2006 data, resulting in a vertical standard error of 0.024 metres for points on open clear ground.
- 2008 ALS data (ground strikes only) has a 4.6 points per m^2 estimated point density.
- Two hundred and fifteen points were used to check the accuracy of the 2008 data, resulting in a vertical standard error of 0.051 metres for points on open clear ground.
- The horizontal accuracy of ALS data points on open clear ground is: 0.55 metres in 2003 (pre-mining), 0.55 metres in 2006 and 0.2 metres in 2008, with a stated vertical accuracy of all datasets is 0.15 metres to 1 sigma.

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ALS Data Analysis

- Umwelt (Australia) Pty Limited where engaged to process the Airborne Laser Scanning (ALS) data of a 6km^2 area of the Mandalong Valley from pre-mining and two post-mining datasets.
- This comparison was undertaken to determine whether ALS is a suitable method of measuring subsidence as a result of longwall mining in the Mandalong Valley by comparison to data collected by conventional survey methods, and the actual subsidence over the mined longwalls.
- The ALS data points sourced by AAM in 2003, 2006 and 2008 were interpolated to obtain grid based digital terrain models (DTM) with grid spacing of 2.0 metres.
- Subsidence values were calculated by comparing the elevation differences between the corresponding points of the DTMs.
- The analysis of the elevation differences of the datasets (i.e. 2003 to 2006 and 2003 to 2008) shows well defined subsidence zones around the areas of longwall mining.

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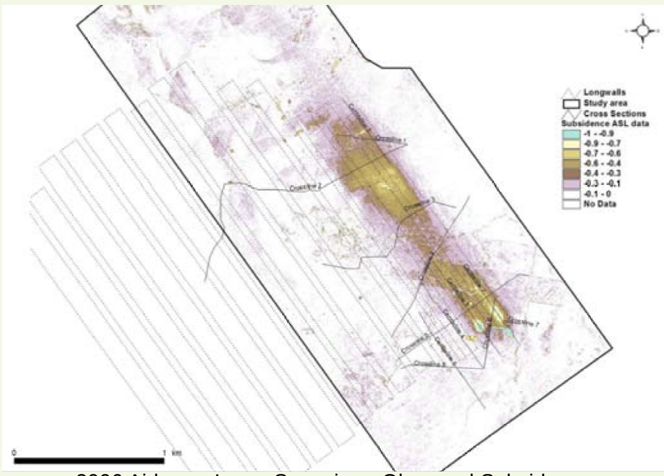
Subsidence Visualisation



2006 Airborne Laser Scanning - Observed Subsidence

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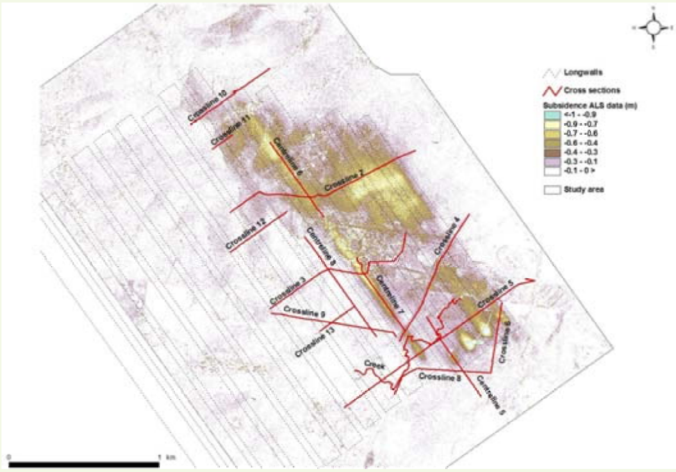
Subsidence Visualisation



2008 Airborne Laser Scanning – Observed Subsidence

Data Comparison

- The calculated subsidence from the ALS data was also compared against subsidence monitoring line data surveyed by Mandalong Mine.
- Conventional subsidence monitoring marks were used to validate the ALS data in areas where these marks existed.
- Comparison of ALS and survey data over a range in topography and vegetation densities.
- The subsidence monitoring line data with the closest date to ALS survey date was compared to the ALS analysis of subsidence.
- Each supplied survey point was compared against the ALS dataset. The difference is calculated as surveyor's elevations minus ALS elevations.

Data Comparison 2006

- Survey data was available at 478 points along 9 survey lines.
- The 2003 to 2006 analysis indicates that there is a good correlation between the geodetic survey measured subsidence and the ALS analysis subsidence for all subsidence monitoring lines, except Centreline 3.
- The average elevation difference between the ALS data and the geodetic survey data (excluding the data for Centreline 3) is 0.031 metres.

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Data Comparison 2008

- Survey data was available at 1250 points along 16 survey lines.
- The 2003 to 2008 analysis indicates that there is a good correlation between the geodetic survey measured subsidence and the ALS analysis subsidence for all subsidence monitoring lines, except Centreline 8.
- The average elevation difference between the ALS data and the geodetic survey data (excluding the data for Centreline 8) is minus 0.013 metres.

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Data Comparison 2008

Cross Section Name	Date of Geodetic Survey	Number of Points	Average Elevations Difference to ALS Data (m)	Minimum Elevations Difference to ALS Data (m)	Maximum Elevations Difference to ALS Data (m)
Crossline 2	02 Jul 2008	163	0.018	-0.427	0.412
Crossline 3	08 May 2008	133	-0.003	-0.252	0.456
Crossline 4 (Deaves Rd)	04 Jul 2008	41	-0.023	-0.243	0.235
Crossline 5	07 Jul 2008	85	0.008	-0.412	0.272
Crossline 6	07 Jul 2008	24	-0.077	-0.273	0.149
Crossline 8	07 Jul 2008	79	-0.063	-0.367	0.187
Crossline 9	12 May 2008	106	-0.077	-0.423	0.106
Crossline 10	27 Jun 2008	84	-0.118	-1.118	0.213
Crossline 11	16 Jun 2008	20	0.094	-0.156	0.280
Crossline 12	16 Jul 2008	54	-0.091	-0.427	0.279
Crossline 13	30 Jun 2008	34	-0.008	-0.118	0.091
Centreline 5	15 Jul 2008	67	-0.101	-0.371	0.110
Centreline 6	02 Jul 2008	74	-0.157	-1.041	0.143
Centreline 7	29 Jul 2008	69	-0.129	-0.517	0.283
Centreline 8	22 Jul 2008	96	-0.285	-0.701	0.192
Creek	08 Jul 2008	94	0.025	-0.583	0.972

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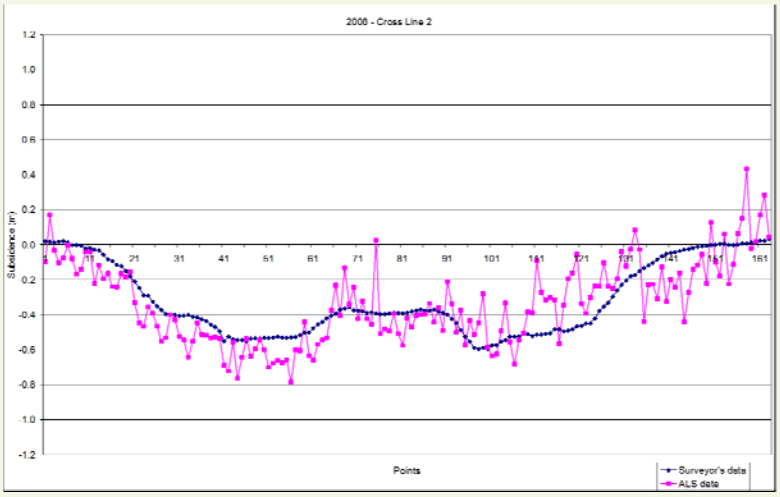
Data Comparison



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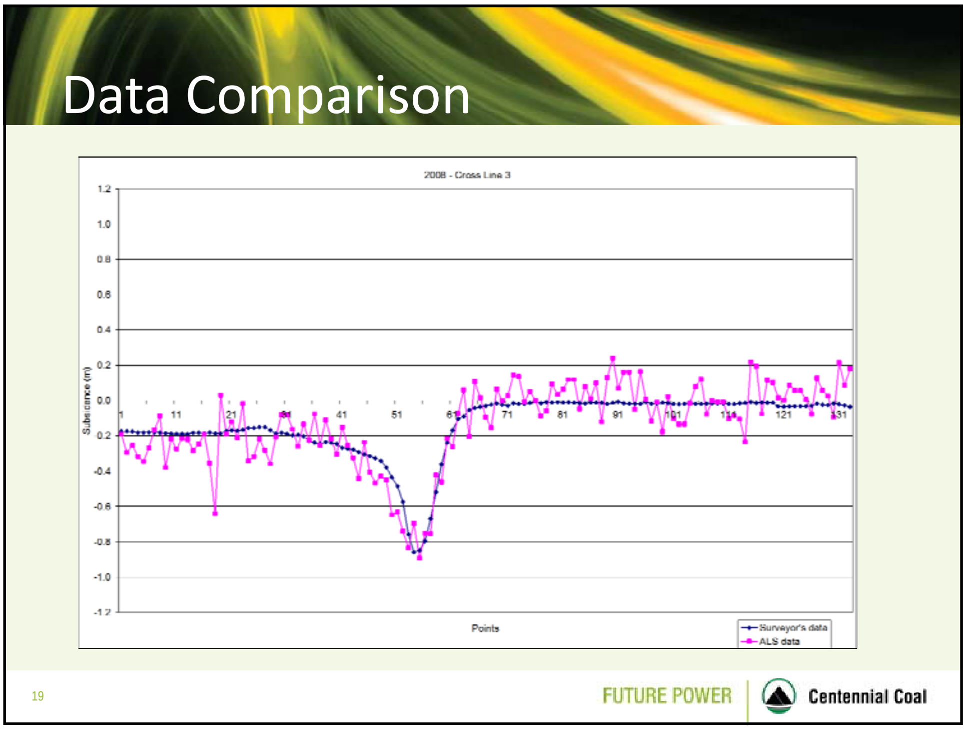
Data Comparison
2008 - Cross Line 3
Subsidence (m)
Points
Surveyor's data
ALS data
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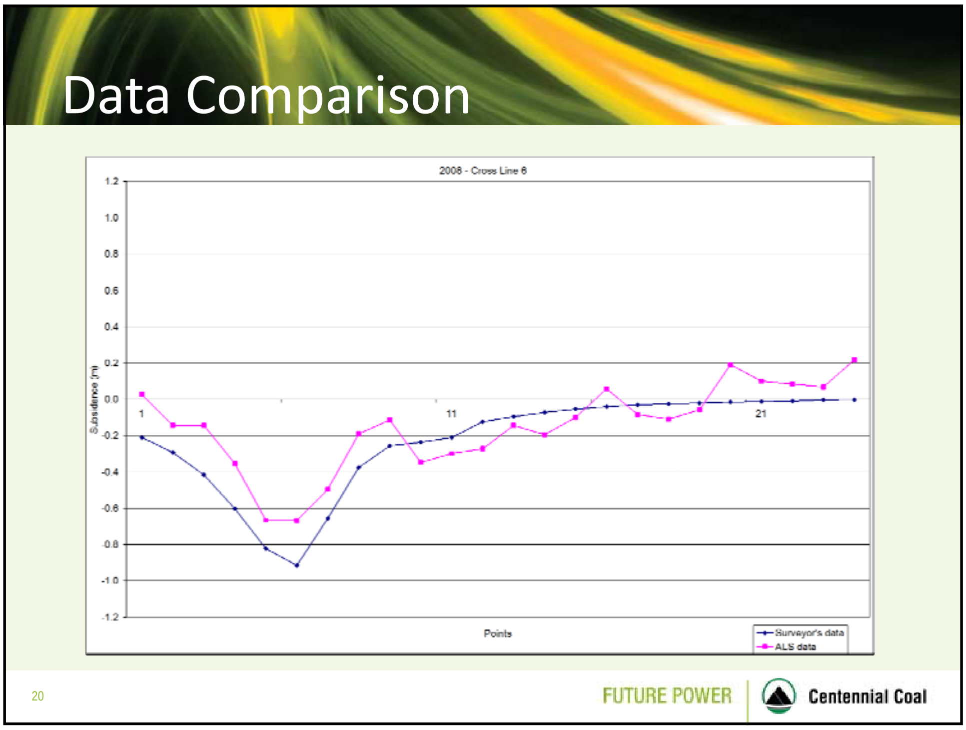
Data Comparison
2008 - Cross Line 6
Subsidence (m)
Points
Surveyor's data
ALS data
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Issues

•The analysis also indicated some areas of significant observed differences between the datasets.

•Some of the differences between the datasets can be described by other factors including:

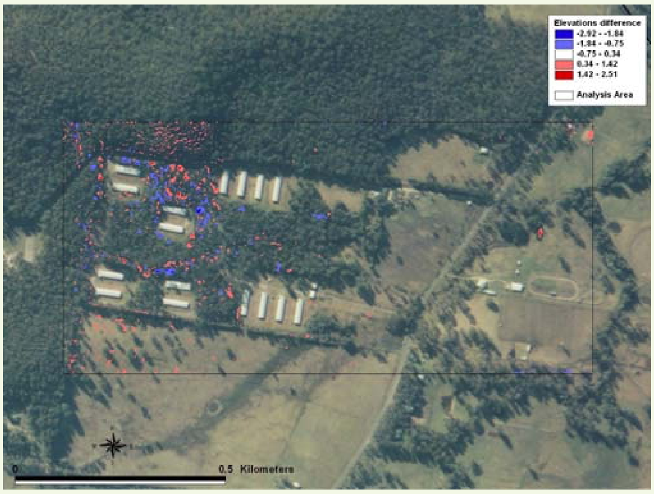
- •Limitations of horizontal and vertical ALS data accuracy influenced by flight direction and size of grid based DTM.
- •Differences in the classification of 'ground' and 'non-ground' data of two ALS surveys (ie change in Algorithm used).

•AAM has indicated that the classification algorithm may be less accurate in isolated pockets of dissimilar terrain/vegetation combinations and under trees.

•This effect was particularly noticeable in areas of high relief (eg creek banks and steep terrain) and low thick vegetation (e.g. noxious weed *Lantana camara*), for the comparison between the 2003 and 2006 datasets.

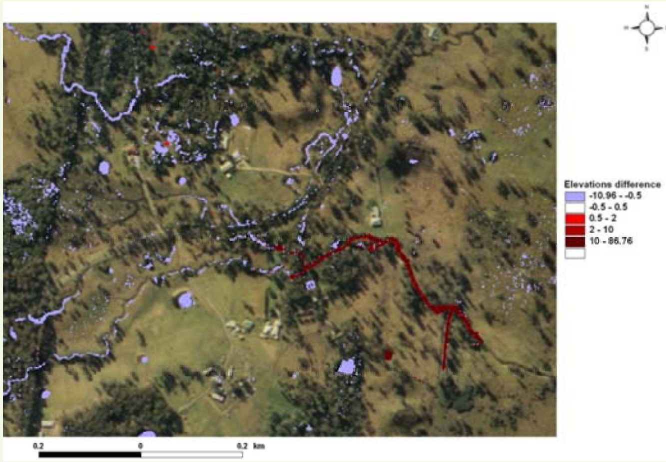
•Changes in elevation of water surfaces (i.e. dams and creeks) at localised landform features within the study area.

Issues



2006 Elevation Differences – Unmined Area (Vegetation)

Issues



2008 Elevation Differences – Unmined Area (Creeks/Dams)

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Conclusion

- The data from the ALS technology provided a detailed dataset enabling temporal comparisons of terrain surface across a broad area that can be utilised to supplement the extensive conventional subsidence monitoring program.
- ALS also provided the ability to obtain data in areas with access difficulties and on private land that would otherwise have been without monitoring.
- The comparison of the Airborne Laser Scanning (ALS) data for the Mandalong Valley for the pre-mining and two post-mining datasets indicates that even with consideration of the outliers in the analysis, the ALS survey produces highly representative terrain data that can be considered to provide a relatively accurate description of the subsidence that has occurred over the entire mining area with a variety of surface topography and vegetation.

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Future

- It is envisaged that ALS monitoring will continue to be used in combination with conventional monitoring, such that the extent and frequency of conventional monitoring may be reduced.
- Future data capture using ALS technology should ensure that as far as possible the parameters are consistent between surveys, including ground point density and processing algorithms.
- Major subsidence line comparisons must be surveyed as close to the date of data capture as possible to reduce any issues surrounding movement occurring between the dates of the two surveys.
- To improve the accuracy of the capture and processing of future data, ALS flight paths should be planned such that they are perpendicular to the slope of terrain to reduce the effect that horizontal position error has on height.
- The ability to improve the accuracy of the ALS subsidence calculation, particularly in area of steep terrain by generating higher resolution digital terrain model grids from existing and especially new data should also be investigated.

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