Use of Mine Planning Software in Mineral Resources and Reserves Estimation of the Lava Lignite Deposit in Servia – Greece

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ABSTRACT

The use of mine planning software in the evaluation and estimation of mineral resources and reserves is well established nowadays in the mining industry for the design and scheduling of surface mines and it is a requirement for the reporting of mineral resources and reserves according to international reporting codes. The fundamental principles of these codes are the transparency of the reported material, the relevance of the information included in the report and the competency of the persons involved in the estimation and reporting process. This paper describes the application of mine planning software in the estimation and modelling procedures of the operational lignite mine of LARCO GMMSA at the Lava deposit in Servia, Kozani. All stages of exploration data analysis, geological modelling, grade estimation, resources reporting, mine design and optimisation, reserves calculation and scheduling of the mining operations are explained. Data integration, advanced 3D graphics and specialised modelling algorithms all within a user-friendly environment contribute to the successful implementation of mining industry accepted procedures to the effective planning and estimation of the surface lignite mine. The more than 10-year long user experience of LARCO GMMSA trained personnel (geologists and mining engineers) adds to the effectiveness of the mine planning software implementation.

1 INTRODUCTION

1.1 Background

The Lava lignite mine is located 12km from the town of Servia and 30km from the town of Kozani in the Kozani Prefecture (Figure 1). Geologically the basin that the coal deposit belongs to, is considered part of the wider tectonic dip that starts from FYROM. That dip having a general direction NNW-SSE was created from the Alpic tectonic activity during Neogene and is consisted of several smaller tectonic dikes. Into these dikes the neogenic lignitic and other sediments were deposited and then unconformably the quartenery formations were overlaid. The area geologically belongs to the Pelagonic zone. The formations encountered from the bottom to the top are:

- Mesozoic crystallic and dolomitic limestones (Triassic – Middle Jurassic).
- Unconformably to the Mesozoic formations, lie the Neogene sediments (clay, silt, sandstone, marl), which contain the lignite horizons.
- Quartenery sediments consisting mainly of conglomarates with clayish or calcious connecting material.

Tectonically the area has faults of small displacement. All the lignite layers converge towards the centre of the basin with an inclination of 5^o. Concerning the Lava deposit, there are two main lignite layers and a minor third that appears at the edges of the basin. The lowest layer has an age of 6.72 – 6.43 Million years and spreads across the central and the most part of the south part of the deposit. Its thickness varies between 1.5 to 25 metres. Its largest part consists of brown coal with alternations with small layers of clay. On top of that layer lies a layer of marl, on top of which the second lignite layer, consisting of compacted coal with a thickness of 2 – 3 metres and has an age of 6.27 – 6.01 Million years. That second layer overlaps the lowest layer and expands furthermore to the north and the south of the deposit. Finally, the third layer that appears at the edges of the basin has an average thickness of 5 metres and lies above the second lignite layer.

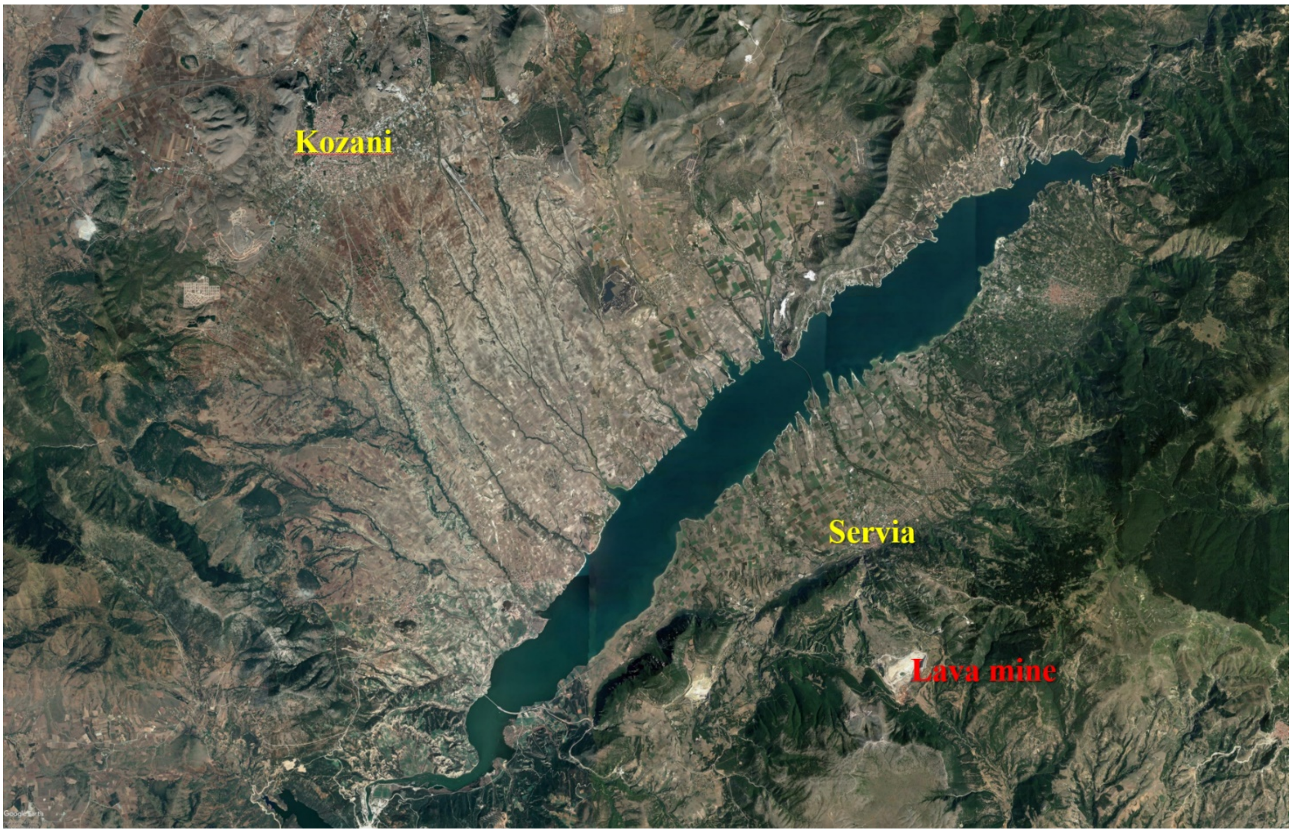

Figure 1. Location of the Lava lignite mine near the town of Servia in NW Greece (image from Google Earth Pro).

1.2 Available Data

The data used in modelling and estimation of lignite resources and reserves of the Lava deposit included 120 drillholes and survey data of the original and current topography. All data were imported into appropriate Maptek Vulcan databases and validated. Figure 2 shows the current topography triangulation model with draped imaged from Google Earth Pro and the location of the drillhole collars. It should be noted that the image data is older than the current topography model.

1.3 Software Implementation

Since 2007, LARCO GMMSA has been using Maptek Vulcan for mine planning in all of its mining operations including the nickel mines in Kastoria, Agios Ioannis and Evoia. The mineral resources and reserves estimation procedure for the nickel deposits has been presented in the past [1]. Maptek Vulcan is also used for mine planning of the lignite operation in Servia which is the subject of this paper. The application of Maptek Vulcan to lignite resource estimation, though for uncorrelated seams, has been presented in the past [2]. However, the steps involved in modelling the Lava lignite deposit and estimating resources and reserves have important differences to the procedure applied to the nickel mines and the other lignite mines in the region, as it will be discussed over the following sections.

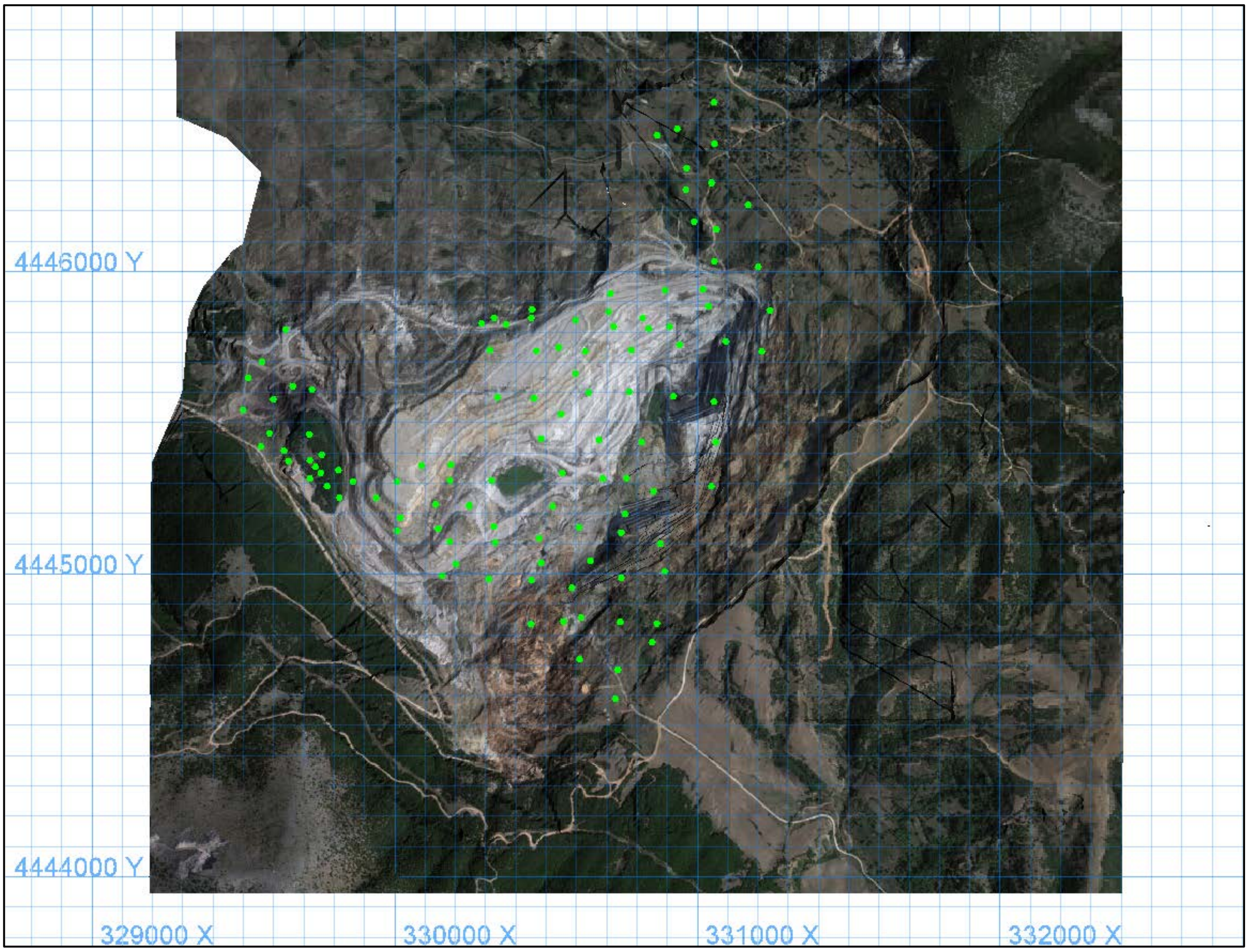

Figure 2. Current topography model with draped image from Google Earth Pro and drillholes collar location.

2 DATA PROCESSING

2.1 Current Topography

Current topography was surveyed by drone and modelled using Pix4Dmapper Pro (Pix4D SA). Figure 3 shows screenshots from the software and produced output using data acquired from the Lava mine. Pix4Dmapper Pro software uses images taken by hand, drone, or plane and creates precise, geo-referenced 3D maps and models used for data analysis. Some of the key outputs of the software include [3]:

- 3D Point Cloud: Accurate digital reconstruction and the geolocation of each point.
- Digital Surface & Terrain Model: the elevation value of each pixel, with or without above-ground objects.

- Orthomosaic: A geolocated high-resolution map with each pixel of the original images projected onto the digital surface model.
- Volume Calculation: Accurate volume calculations on a representation of stockpiles, with fully-adjustable base height.
- Contour Lines: A simplified representation of the topography with closed contours displaying the elevation.
- 3D Textured Model: Triangular mesh with photorealistic texture.
- Reflectance Maps: reflectance based on the pixel value in multispectral or thermal imagery.
- Index Maps: indices such as NDVI and NDRE or create of custom indices.

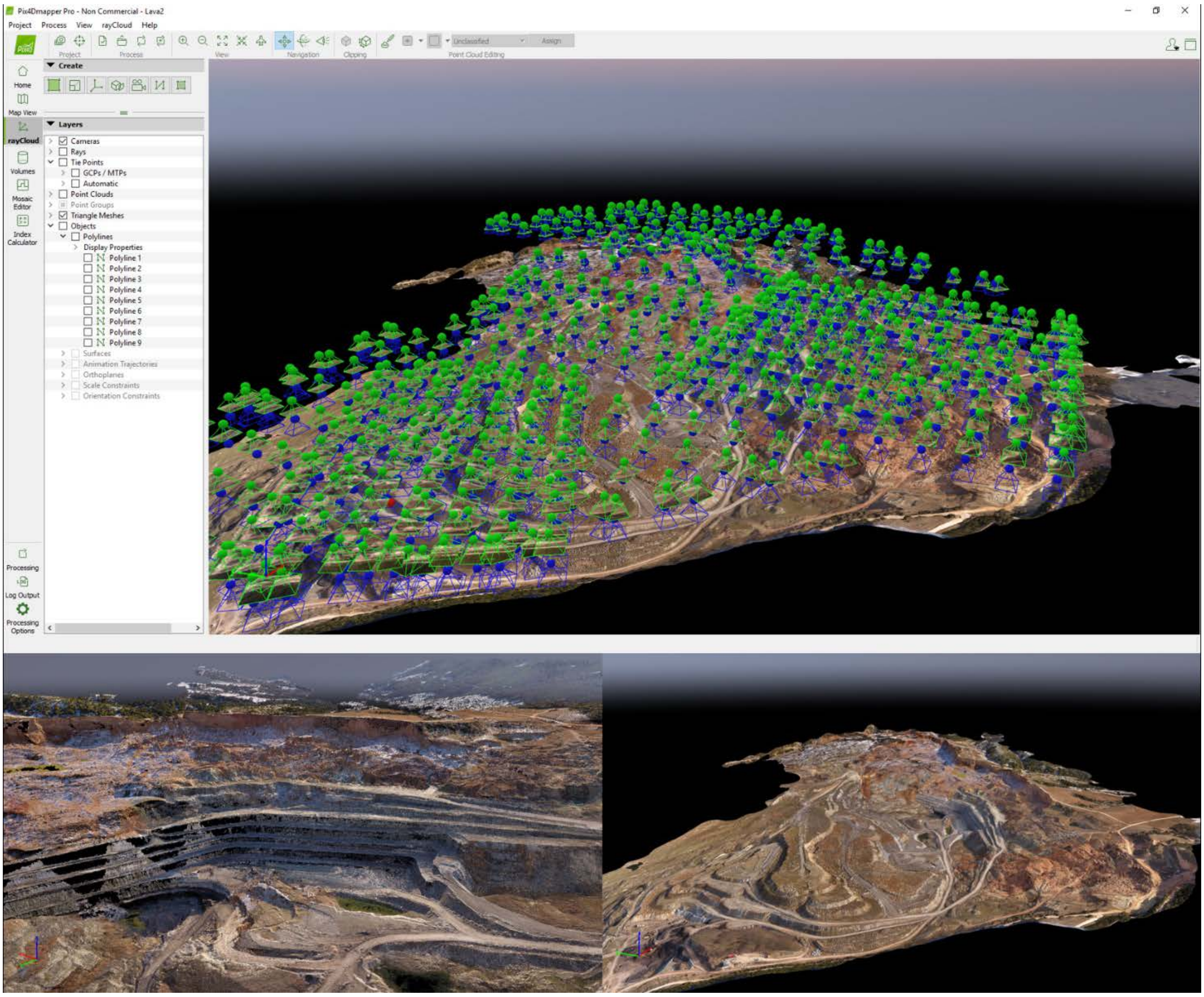

Figure 3. Screenshots from topography drone scan in Pix4Dmapper Pro (top: camera locations and triangulation model, bottom left: point cloud, bottom right: triangulation model).

The triangulation model produced by Pix4Dmapper Pro was imported in Maptek Vulcan to be used for lignite resources and reserves modelling.

2.2 Drillhole Database Development and Validation

Data from the 120 drillholes were imported to a drillhole database in Maptek Vulcan through CSV files containing collar information (hole ID, collar XYZ) and sample intervals (top and bottom depth, length, lithology, ash, etc.). The database was checked and validated both visually and through a number of tests related to collar coordinates and overlapping intervals. A separate database lithology table was generated by combining consecutive intervals of the same lithology. This table and lithology field were used to create drillhole sections in Vulcan and proceed with the correlation of lignite layers. The resulting correlation was stored in an extra field in order to have both the original lithology and the interpretation.

Sample intervals were composited to a standard length of 0.5m as they were originally of varying length, thus not suitable for block model estimation. The choice of composite length was based on the mining method used.

3 GEOLOGICAL MODELLING

The correlated lignite layers intervals were further processed and used to build grid models of the roof and floor of each layer (Figure 4). The grid models were cropped by the current topography surface and were checked against drillholes in sections. Minor layers of low lignite quality (waste) within the three main lignite layers were also modelled separately. Blocks inside these waste layers were to be excluded from estimation, as were the composites that came from these layers to minimise dilution.

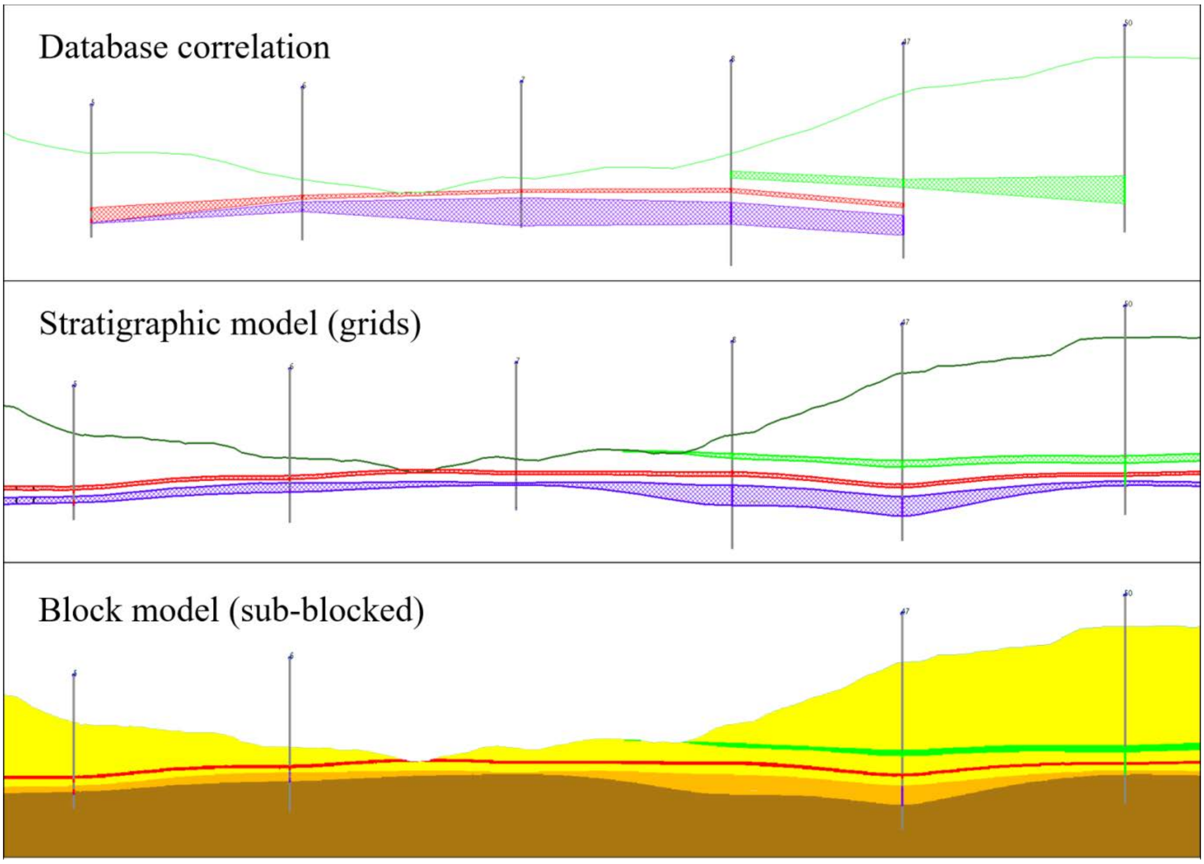

Figure 4. Example section showing database lignite layers correlation between drillholes (top), grid models representing stratigraphy (middle), and complete block model containing both structural and quality information of the lignite deposit. Drillholes missing in the bottom section are hidden behind the block model section.

4 LIGNITE RESOURCES ESTIMATION

The structural grid models of stratigraphy and the current topography triangulation model were used to create a sub-blocked block model. The main block size was set to 10x10x10m while the sub-block size ranged from 1x1x0.5m up to the main block size. The block model origin and extents were set in a way to cover all the area of interest in all three coordinate axes. Several block variables were defined allowing storage of quality estimations, lithology, resource classification and estimate validation parameters. The following table gives a summary of the main block model parameters.

Table 1. Block model parameters – all dimensions and coordinates are in meters.

Type	Sub-blocked - unrotated	**Number of variables**	19
Origin X	330,000	**Main block size X**	10
Origin Y	4,444,000	**Main block size Y**	10
Origin Z	650	**Main block size Z**	10
Extent X	2,200	**Minimum sub-block size X**	1
Extent Y	3,200	**Minimum sub-block size Y**	1
Extent Z	550	**Minimum sub-block size Z**	0.5

Sub-blocking occurred only in cases where a main block intersected one of the surfaces included in the model, i.e. lignite and waste layers roof and floor surface, and the current topography surface. Maptek Vulcan initially breaks the main block to sub-blocks of the minimum size (1x1x0.5m in our case) and then joins together sub-blocks that no longer intersect the surface that caused the sub-blocking (a process called coalescing in Vulcan), thus leading to sub-blocks of sizes multiple of the minimum size (e.g. 2x2x2.5m). The aim of this process is to reduce the number of sub-blocks down to the absolutely necessary while still following the controlling surface to the greatest resolution possible.

All blocks were coded based on the controlling surfaces so that they belong to a particular zone of the deposit. The coding values were stored in a lithology variable that could be later used to select blocks for estimation, processing and reporting. The bottom section in Figure 2 shows the blocks coloured according to this variable.

Once the block model was constructed, multiple estimation runs were defined targeting the blocks of each lignite layer (block model zone). A single estimation run was used to estimate each layer with the resource classification of the produced estimates taking place afterwards through block model scripting. The main estimation parameters used in all lignite layers quality estimation are summarised in Table 2.

Table 2. Main lignite quality estimation parameters.

Search Ellipsoid		**Other Parameters**	
Bearing	0	**Minimum samples**	4
Plunge	0	**Maximum samples**	16
Dip	0	**Maximum samples per octant**	2
Major	200	**Discretisation along X**	4
Semi-major	200	**Discretisation along Y**	4
Minor	50	**Discretisation along Z**	1

The inverse distance squared weighting method was used to estimate ash and other quality variables in the block model. Ash and the other lignite quality parameters were considered to vary along all three axes (i.e. even along Z) within each layer, unlike the strictly stratigraphic approach of estimating qualities using grids.

Each block was split into 4x4x1 points (discretisation) which were estimated separately and then averaged to produce the final block value. This is a just a practical way to better approach the distribution of the estimated parameter within the block volume as inverse distance weighting is a point and not a volume estimator. As already mentioned, estimation was performed separately for each lignite layer, i.e. only blocks being inside the specific layer were estimated using sample composites only from that layer. Octant based search was used to ensure sample selection from surround drillholes to the block being estimated as shown in Figure 5. After estimation, it was possible to check how the sample selection strategy worked by using a special "Explain" function of Vulcan which allows the user to see graphically which samples were used in the estimation of a particular block and estimation related information about them (applied distance, applied weight, octant number, etc.) as shown in the detail window in Figure 5.

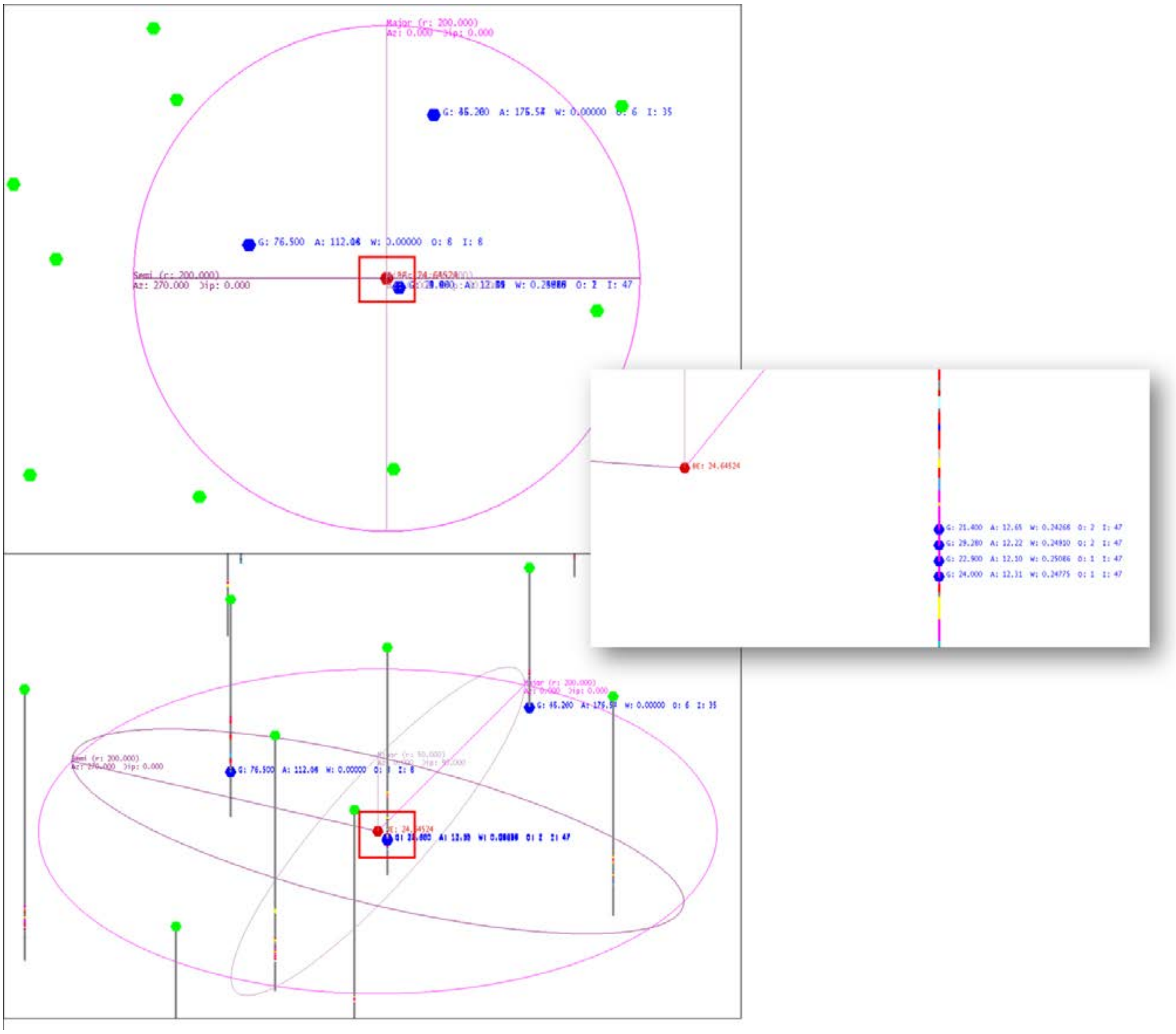

Figure 5. Plan and 3D view of search ellipsoid used to estimate ash in the lower lignite layer. The red box shows the area of the detail view on the right. The block in question is shown with a red dot while the selected samples are shown in blue.

Figure 6 shows a section through the block model coloured by ash content estimates. Estimates presented good agreement with the drillhole interval values. Generating a grade/tonnage curve for ash required some manipulation of the table produced by the corresponding function in Maptek Vulcan. The software expects a grade parameter and the tonnage calculated for each cutoff includes the blocks with an estimated grade value higher than the cutoff. In the case of ash, we need to report the material with an ash value lower than the cutoff so it was necessary to effectively reverse the tonnage table and reproduce the graph as shown in Figure 7. The curves show the sensitivity of lignite ash content and tonnage to the ash upper limit applied. It seems that after 60% there is little or no change on lignite ash and tonnage.

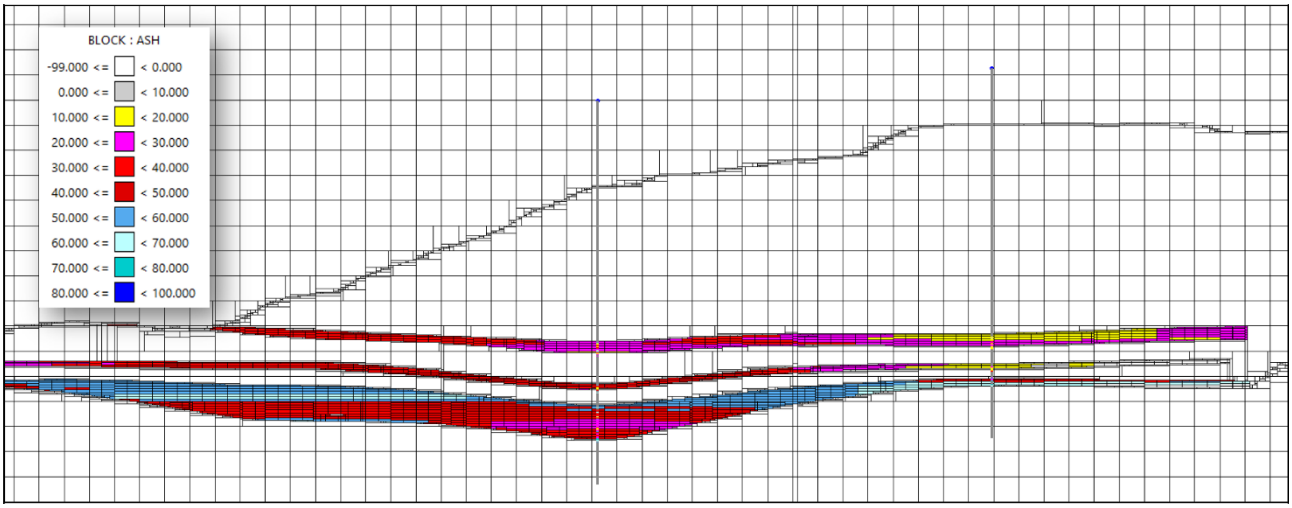

Figure 6. Block model section showing ash estimation inside each of the three lignite layers.

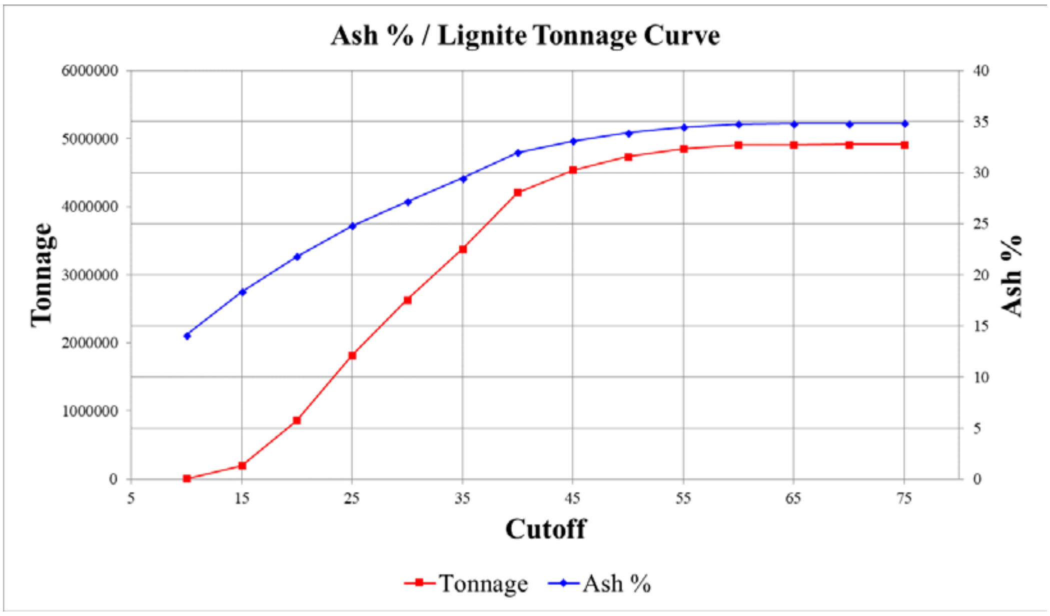

Figure 7. Grade/tonnage curve of lignite resources showing the effect of applying a different ash upper limit (cutoff).

Figure 8 below shows the results of drift analysis and comparison between the composited ash values used as input to resource estimation and the produced block estimates of ash. The smoothing effect of block model estimation with inverse distance is clear mainly along the X and Y axes. The histogram also shows that the block estimates distribution is narrower than the composites, which is normal (support effect). Generally, the estimates follow the main trends of the composites.

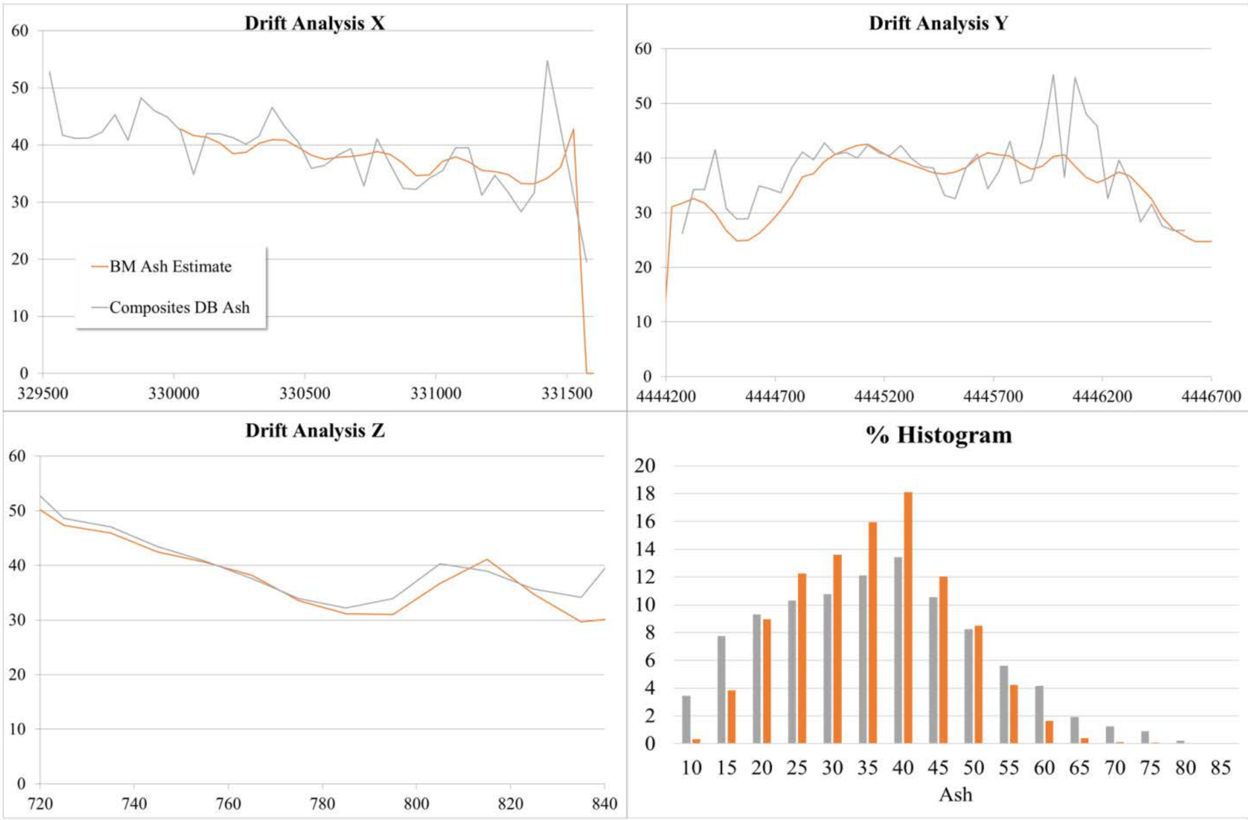

Figure 8. Drift analysis and histogram of composites database ash values and block model ash estimates.

5 LIGNITE RESERVES CALCULATION

For the lignite reserves calculation, a solid triangulation of the conceptual final pit was used to limit the considered volume. The final pit was derived using Lerchs-Grossman pit optimisation with some standard financial and pit slope parameters (Figure 9). Table 3 summarises the lignite reserves estimate for the Lava mine based on the mining operation at the start of 2018. Two scenarios are presented based on a different upper limit for ash (50 or 60%).

Table 3. Lava lignite mine reserves at the start of 2018.

Ash 50%								
Lignite kTonnes	**Ash** %	**Waste** m^3 x1000	**SR** m^3/t	**Sector**	**Lignite** kTonnes	**Ash** %	**Waste** m^3 x1000	**SR** m^3/t
2,420	34.89	26,623	11.00	North	986	34.35	8,749	8.88
				Central	643	37.01	5,372	8.36
				South	792	33.84	12,503	15.79
Ash 60%								
Lignite kTonnes	**Ash** %	**Waste** m^3 x1000	**SR** m^3/t	**Sector**	**Lignite** kTonnes	**Ash** %	**Waste** m^3 x1000	**SR** m^3/t
3,040	38.85	26,107	8.59	North	1,056	35.59	8,690	8.23
				Central	962	42.67	5,105	5.30
				South	1,022	38.62	12,311	12.05

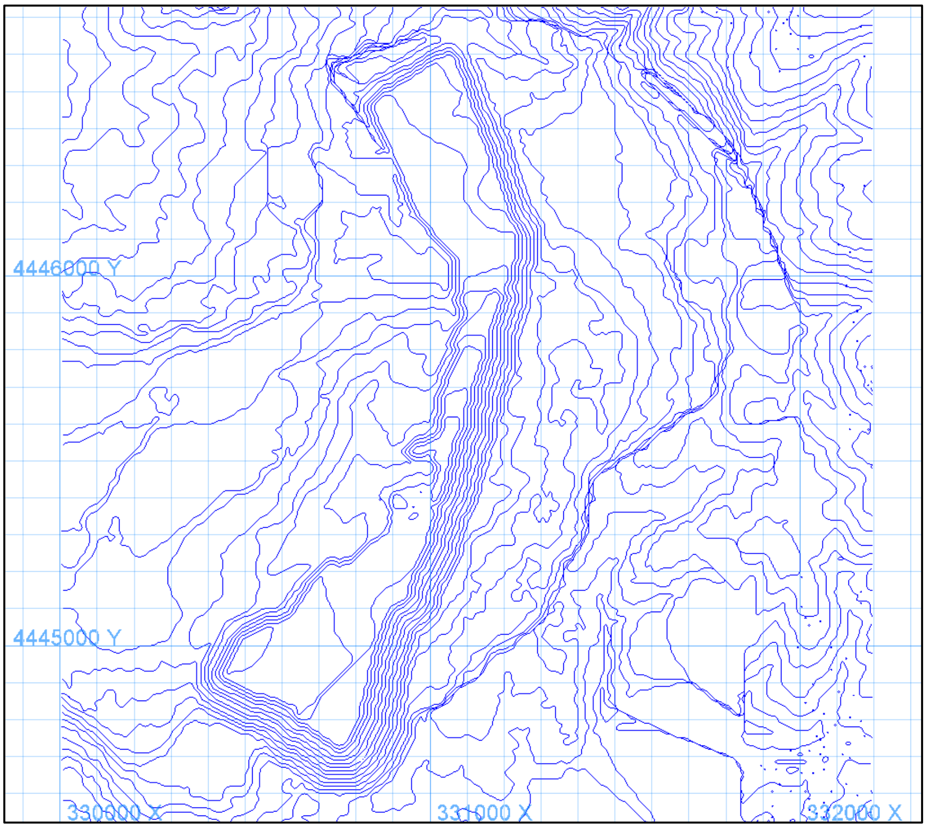

Figure 9. Optimised pit limits of the Lava lignite mine used to limit the material reported as reserves.

6 CONCLUSION

This paper discussed most aspects of the application of mine planning software to the evaluation of lignite resources and reserves of the Lava lignite deposit in NW Greece. The implementation of mine planning software produced results that increased confidence as to the available resources, formalised the mine planning procedure, aided the configuration of the mining methods applied, and helped in planning future mining operations by developing different mining scenarios with speed and clarity. Adopting the discussed approach increased confidence in the produced results and reduced the risks associated with the estimates, ensuring all important geological controls are considered. The use of a pit optimisation tool helped convert resources to reserves with more confidence and in a more standardised fashion that is widely accepted by the mining industry.

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