Visual Impact Assessment of Seaside Quarrying Operations and Planned Restoration

I.K. Kapageridis
Technological Education Institute of Western Macedonia, Greece

D. Tsipras
LAVA Mining and Quarrying SA, Greece

ABSTRACT

Digital photography combined with three dimensional models of topography, mining operations and restoration plans can lead to extremely realistic images and animations of the current and future states of a mine or quarry. The amount of work and the time required for the successful modelling of a mine and its restoration plan are surprisingly low nowadays. All these mean that the visual impact of mining and quarrying operations can be easily assessed using common computer hardware and some dedicated software packages. LAVA Mining and Quarrying SA is a company committed to strive continuously for the highest possible environment protection at the company's quarries. The pozzolanic rock quarry located at Xylokeratia is one of the company's quarries on the island of Milos and the subject of the study presented in this paper. A thorough restoration plan of the Xylokeratia quarry is being completed by the company. For its purposes, a complete visual impact assessment study was performed at the Department of Geotechnology and Environmental Engineering of the Technological Education Institute of Western Macedonia. The procedures used in this study and the produced visual results are presented in this paper.

1. INTRODUCTION

This paper describes the results obtained and the procedures followed during the visual impact assessment study of the expansion and restoration of the pozzolanic rock quarry in Xylokeratia, Milos island (Kapageridis, 2005). This study was performed at the Department of Geotechnology and Environment of the Technological Education Institute of Western Macedonia, Greece using topographical data and images provided by LAVA Mining and Quarrying SA.

The main aim of the study was the evaluation of the visual impacts of a proposed quarry expansion and restoration plan, particularly considered from viewpoints offshore. The quarry expansion is expected to expose, from certain angles, parts of the site that are not visible today. The study aimed at identifying the areas of exposure and their visibility from viewpoints of interest.

The comparison of the existing situation with the restoration phase is performed on the basis of topographical maps of the site and surrounding area and of the proposed final restoration phase.

2. DATA REQUIREMENTS

2.1 Overview

Required data for this study include vector data concerning the geometry and location of various features and objects and raster (photographical) data describing the way these objects are viewed due to vegetation, rock types, roads, etc. Vector data was provided in AutoCAD file format, two dimensional for the restoration phase and three dimensional for the current quarry site (Figures 1 and 2).

2.2 Raster Data

All images were collected during a site visit using a high resolution digital camera. Multiple shots were taken from inside and around the quarry as well as offshore. An aerial photograph of the site area from an earlier production stage was added to the available raster data. The digital images show views of the quarry as it looks today from sea and land.

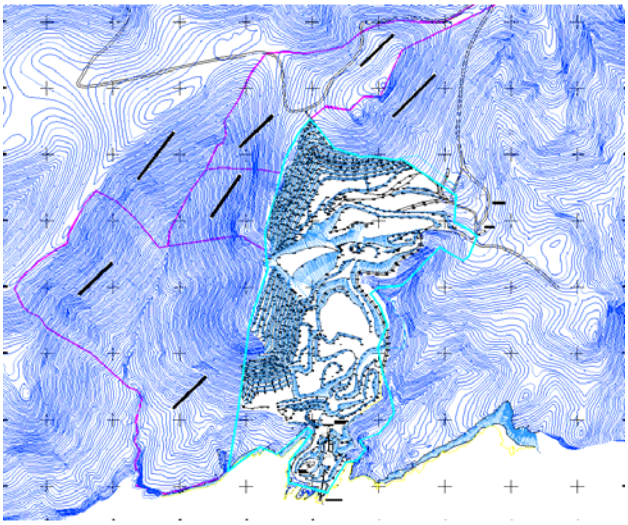

Figure 1: Topographic map of the current quarry site.

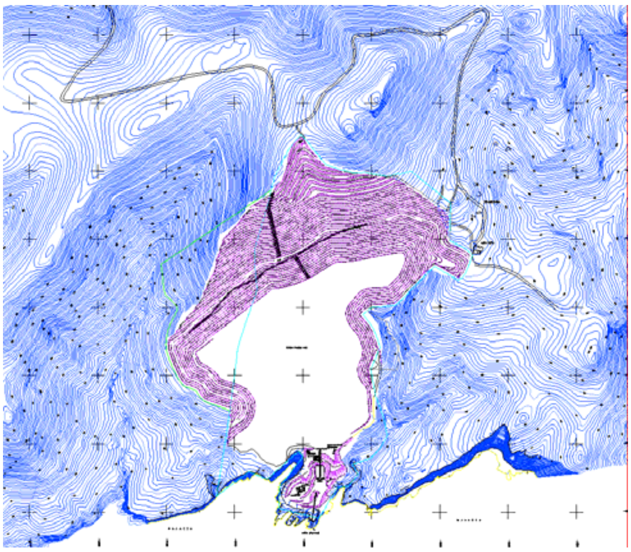

Figure 2: Topographic map of the quarry site after restoration.

2.3 Vector Data

All vector data were saved in DXF (Data eXchange File) format in AutoCAD and then imported to VULCAN, a general mine planning package integrating advanced modelling and visual functionality (Neilson et al. 2000). A database was created that is available to the company for quick model development further from the purposes of this study.

3. MODELLING PROCEDURE

Importing of vector data from AutoCAD to VULCAN enabled their thorough processing in three dimensions. The three-dimensional map of the existing site as displayed in VULCAN is show in Figure 3.

The restoration phase map was in two dimensions, i.e. all contours had the same elevation. Using the major contour annotations of the map, all contours inside the quarry area received correct elevations and thus the map was converted to three dimensions. The topographical surface outside the quarry was obtained by re-limiting the existing topography to areas outside the restoration phase quarry site (Figure 3).

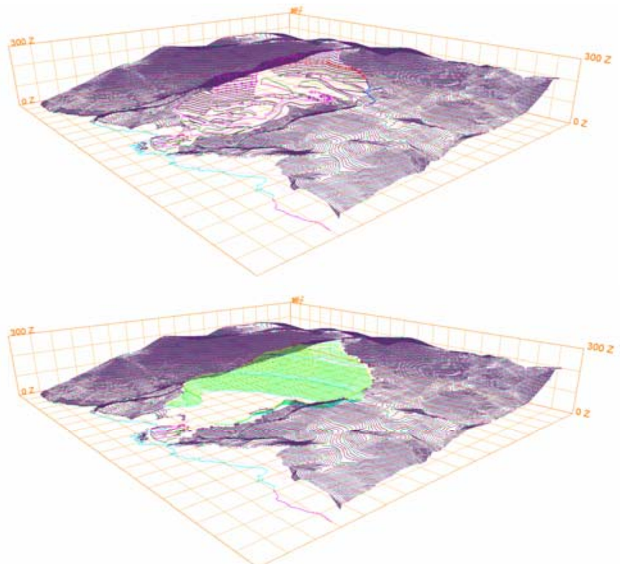

Figure 3: 3D Topographic map of the current quarry site (top) and after restoration (bottom).

With all vector data of the topography from the two phases in place, it was possible to generate surface models inside and outside of the quarry area. These models are triangulations constructed using the Delaunay algorithm that leads to triangular faces as equal-sided as possible. The various contour and other points are joined to form triangles, the sides of which cannot cross contour lines. In other words, contours are used as break-lines and the linkage of non-sequential contours is avoided, preventing the construction of a non-representative model. These triangular faces are colored and shaded using a virtual light source in order to give a sense of a three-dimensional surface to the viewer (Figure 4).

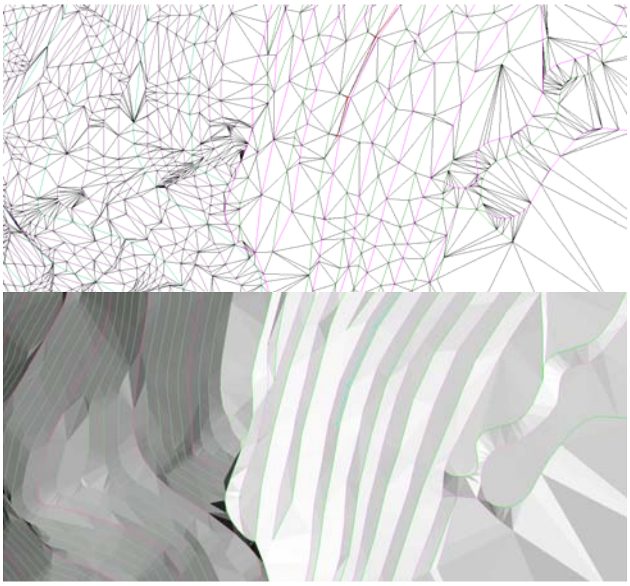

Figure 4: Triangulation model of topography in network and shaded form.

The triangulation surface models also allow volumetric calculations between phases with high precision. In this study the following surface models were constructed:

1. Topography surface outside quarry area of existing phase.
2. Existing quarry area surface.
3. Shore face surface.
4. Topography surface outside quarry area of restoration phase.
5. Restoration phase quarry area surface.
6. Sea level surface.

In addition to the surface models, a series of trees were added in the restoration phase at a constant distance between them along all benches and the quarry floor. These trees are used when obtaining static images in order to get a more representative view of the final aesthetical result of the restoration. These trees are nothing more than a symbol built inside the software from line segments of different length, thickness, angle and color as shown in Figure 5.

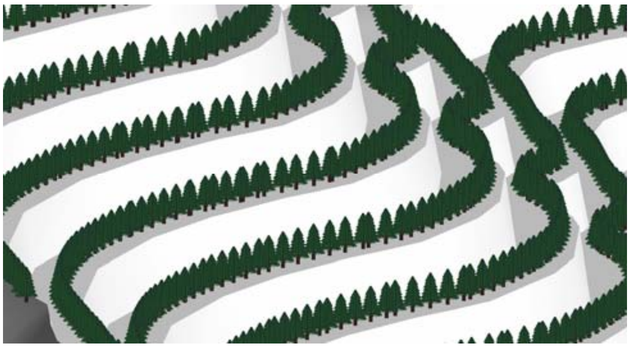

Figure 5: 3D view of restoration phase model with trees on each bench.

4. USE OF RASTER DATA

A key role in the development of realistic static images and video of three-dimensional models play the properly draped (correlated) digital photographs that provide realistic texture and colour to model surfaces. The use of triangulation models already provides a sense of three-dimensional geometry to the viewer for the surfaces considered. However, the visual result becomes fully realized only after the draping of corresponding photographs on the surface of these models.

For surfaces representing topography it is usually sufficient to drape a fairly recent aerial photograph that covers the coordinate extents of the model and has sufficiently high resolution to enable obtaining static images from close distances without severe pixelation – pixels shown as large squares of same color when image is viewed from very close. In cases where the topography contains an excavation of some kind, such as an open pit or quarry, that has steep (near vertical) faces, an aerial photograph is not sufficient. Aerial photographs of open pits commonly show benches with dark shading (like thick gray stripes) and loss of colour and texture. Therefore, in such cases it is necessary to obtain photographs from directions vertical to the benches and this is possible from inside the excavation. The same principle applies to rocky and steep shores with near vertical surfaces. In this study all necessary photographs were taken covering the surface of the quarry and the shore close to it. The following images (Figure 6 and 7) show the aerial photograph used in this study as well as some representative photos from the quarry and the shore.

Figure 6: Aerial photograph of quarry site from an earlier production stage.

The on-site photographs were combined in larger images that cover the area of the model surface on which they are draped. The correlation process is quite sensitive particularly when the exact location of shooting them is not well defined or their scale is not constant in different directions. During the draping process, we are trying to correlate image pixels to model world coordinate points as shown in Figure 8.

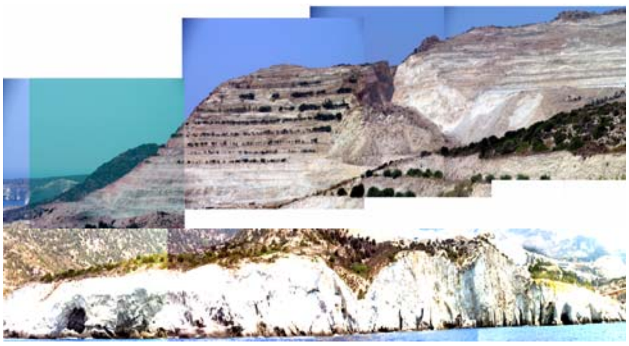

Figure 7: On-site digital photographs forming panoramic views.

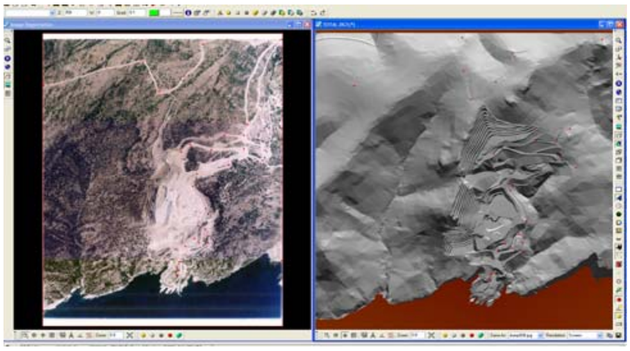

Figure 8: Aerial photograph and triangulation model correlation in plan view.

Every correlation point added affects not only the particular pixel but the entire area around it which can extent all the way to the image border if there are no other correlation points in between. Thus, the correlation points are selected with great care and purpose. Commonly the points chosen display a distinct feature of the surface, such as points on a road, the shoreline, a river, a ridge or inside the excavation. In the case of the aerial photograph these points are picked in plan view. Photographs taken in other planes are correlated with the model surfaces rotated to match the plane of the photograph and enable easier digitizing of correlation points (Figure 9).

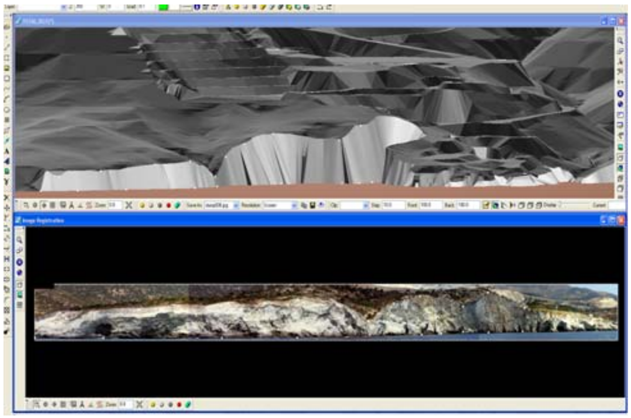

Figure 9: On-site digital photograph and triangulation model correlation in side view.

After correlation is complete, the triangulation models are loaded on screen with the appropriate image textures that get further shaded according to the underlying model geometry and a virtual light source. The model space is displayed in perspective view and the entire environment is lighted and coloured to give the sense of a sky and present a more realistic visual result (Figure 10).

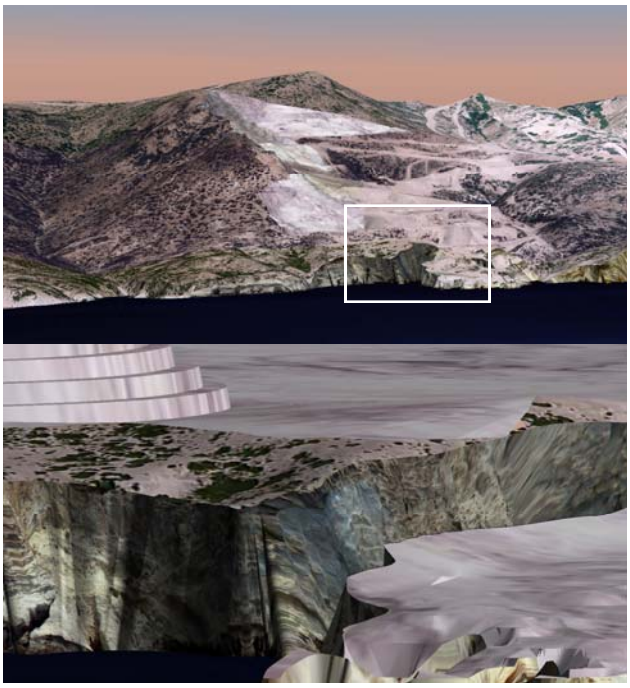

Figure 10: End result of image and model correlations (top) and detail showing area with three different images (below).

It should be noticed that the surface of the quarry in the restoration phase is unknown and thus a part of the existing phase texture is draped arbitrarily on the surface of the quarry for this phase. The part of the texture is selected so that it does not contain any distinct geometrical features of the excavation and is simply used to assign proper texture and colour attributes to the model.

5. OBTAINING STATIC IMAGES AND VIDEO

After the construction of the models and image correlation, it is possible to obtain static images and video from any viewpoint and angle with or without perspective. Initially the viewpoint is selected in the model space from where we are looking to the models and then we choose the viewing direction as shown in Figure 11.

With the proper view selected, any modelled phase of the quarry can be loaded on screen. Thus we can get the picture of the site as it is today and as it will be after restoration from exactly the same viewpoint and direction. This process is repeated as many times as necessary from different viewpoints while the pictures can be stored in files of different image formats (bmp, jpg, png, gif, etc.)

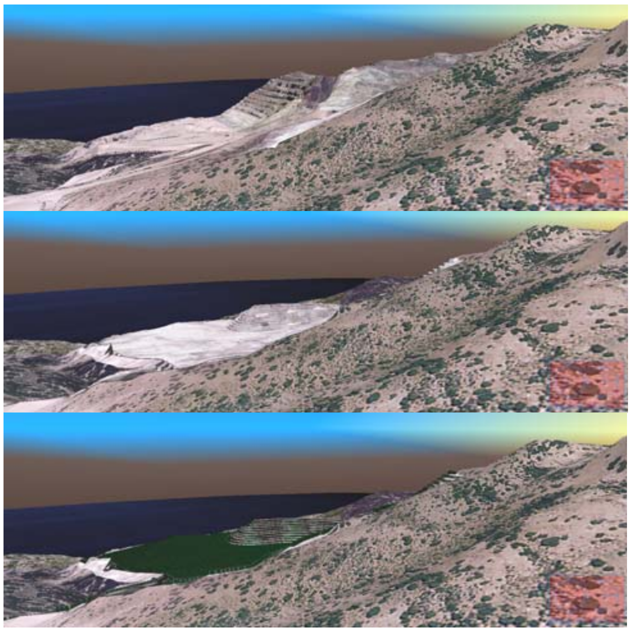

Figure 11: 3D view from a distant viewpoint of the existing site (top), restoration phase (middle) and with grown trees (bottom).

It is understandable that parts of the topography not included in the vector data used to construct the models are not visible in these pictures. The possibility still exists to combine the pictures from our models with real photographs taken from the same viewpoint and direction to get a complete view. It should be noticed though that this process can present great difficulty particularly when we combine photographs of the current situation with pictures for future phases where certain parts are exposed that belong to areas not covered by the available vector data and are not visible even on the actual photographs. Such cases call for viewer imagination.

An example of such case is the east side of the area modelled in this study where another company's quarry is located and not included in the vector data. In this case it is practically impossible to obtain the complete visual impact of the quarry expansion as it will expose parts of a nearby excavation not part of the model. The following images (Figure 12) show the quarry from a close viewpoint at the east looking west. Figure 13 also shows the two phases on top of each other, with the surface of the existing phase transparent so that the viewer can understand better the difference between the two.

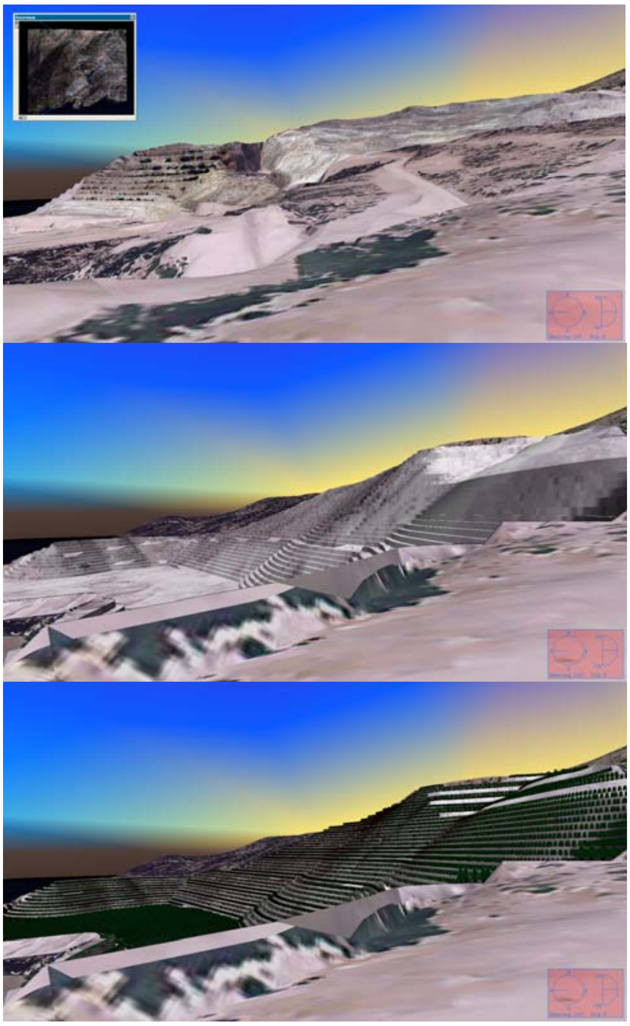

Figure 12: 3D view from a close viewpoint of the existing site (top), restoration phase (middle) and with grown trees (bottom).

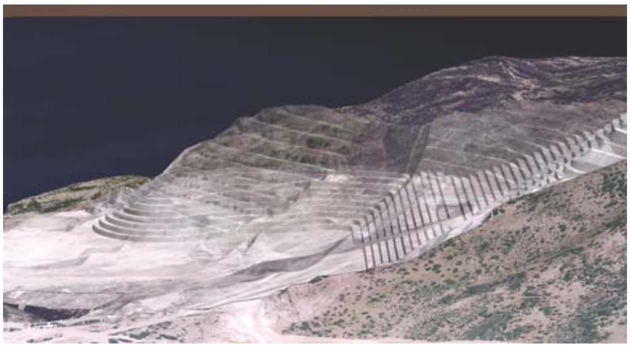

Figure 13: Surface models of existing phase (transparent) and restoration phase.

The models in both phases can be viewed from critical locations such as the route of boats close to the shore. It is also possible to generate video by digitizing a route and then following it while always looking at a point of interest such as points in the quarry area (Figure 14). The making of such video can take hours to process but the end result can be written on DVD recordable media for viewing with standard DVD players without the need of a computer.

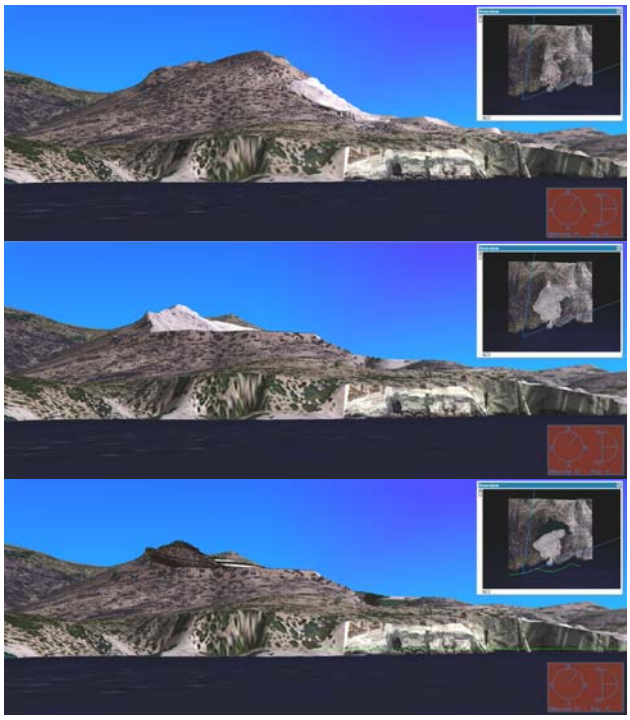

Figure 14: 3D view from an offshore viewpoint of the existing site (top), restoration phase (middle) and with grown trees (bottom).

5. CONCLUSIONS

This paper has described the procedures used in a visual impact assessment study of a seaside quarry operation. The study has demonstrated the benefits of integrating vector and raster data from various sources in an advanced graphical environment and the possibilities provided by current software and hardware technology.

REFERENCES

Neilson, L. & Kapageridis, I.K. (2000). Environmental Management with VULCAN. In: Ibarra-Berastergi et al. (eds). Development and Application of Computer Techniques to Environmental Studies VIII (ENVIROSOFT 2000), WIT Press, Southampton.

Kapageridis, I. (2005). Visual Impact Assessment Study of Quarry Expansion and Restoration Plan, Technical Report, LAVA Mining and Quarrying S.A.