Technological and Integrated Approach to Open Pit and Underground Mining Project Processes

Açık Ocak ve Yer Altı Maden Projelendirme Süreçlerinde Teknolojik ve Bütünleşik Yaklaşım

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ABSTRACT

The most important reason for the occurrence of a large number of occupational accidents in the mining sector in our country is that mines are not designed properly in the principles of science and technology. Modern mining science and technology require that before exploitation of the mines, pit optimization be made, three dimensional models be developed, reserves be estimated, mining method be determined, and production planning be developed.

The fact that mines are nonrenewable and irrevocable assets require that mineral resources be utilized sustainably at the highest benefit of society for future generations.

In this study, iterative mining project approaches for realizing every stage of both open pit and underground projects at every scale using information technologies are given in the following main titles.

i. A preliminary analysis to determine license area, landslide susceptibility and hydrological risk analysis,

ii. Volume calculations and preparing production maps for annual mineral reserve production,

iii. Evaluation of the drilling data, creating solid models from surfaces and cross-sections,

iv. Block modeling and geostatistical estimation procedures,

v. Open pit design,

vi. Blasting design,

vii. Environmental impact assessment (EIA) analysis,

viii. Waste road designs,

ix. Underground production plans and gallery designs.

Project applications in this paper was implemented using Netcad technologies.

Keywords; Three-Dimensional Ore Modeling, Open Pit Design, Geostatistics

ÖZET

Ülkemizde madencilik sektöründe çok sayıda iş kazası meydana gelmesinin en önemli nedeni madenlerimizin bilim ve teknoloji ilkeleri çerçevesinde doğru tasarlanmamış olmalarından kaynaklanmaktadır; oysa çağdaş madencilik bilim ve teknolojisi, madenlerin çıkarılmadan önce; ocak optimizasyonlarının yapılmasını, üç boyutlu olarak modellenmesini, olası rezerv kestirimlerinin yapılmasını, üretim yönteminin belirlenmesini ve üretim planlarının yapılmasını gerektirir.

Madenlerin yenilenemez ve yerine konulamaz nitelikte varlıklar olmaları, maden kaynaklarının en yüksek fayda ile gelecek nesilleri için sürdürülebilir yapıda toplum yararına kullanım gerekliliğini de zorunlu kılar.

Bu çalışmada her ölçekteki açık ocak ve yer altı maden projelerinin her aşamasının bilişim teknolojilerinden yararlanılarak gerçekleştirilmesine yönelik iteratif madencilik projelendirme yaklaşımları aşağıdaki ana başlıklar kapsamında yer almaktadır;

i. Ruhsat sahalarının belirlenmesinde ön analizler, heyelan duyarlılığı ve hidrolojik risk analizlerinin gerçekleştirilmesi,

ii. Üretim hattı boyunca yıllık maden rezerv projelerinin, üretim haritalarının oluşturulması ve hacim hesaplamaları,

iii. Sondaj verilerinin değerlendirilmesi, yüzeylerden ve en kesitlerden katı model oluşturma,

iv. Blok modellemesi ve jeoistatistiksel kestirim işlemleri,

v. Açık ocak tasarımı,

vi. Patlatma tasarımı,

vii. Çevresel etki değerlendirme (ÇED) analizleri,

viii. Ocak pasa yol tasarımları,

ix. Yer altı üretim planları ve galeri tasarımları.

Bu bildirideki proje uygulamaları NetCad teknolojileri kullanılarak gerçekleştirilmiştir.

Anahtar Kelimeler; Üç Boyutlu Cevher Modelleme, Açık Ocak Tasarımı, Jeoistatistik.

1. SITE SELECTION ANALYSIS OF LICENCE AREAS

1.1 Use of Raster and Online Maps for Exploration and Production Areas in Projects

The raster (base map, geological map, etc.) maps of the site where exploration and production activities will be carried out are geographically referenced and are added to the project screen with online maps. (Figure 1.1).

1.2 Transferring and Constraining the Operating License Boundary Coordinates to the Project

Mining license boundary coordinates where exploration and production activities are carried out have been transferred to the project together with previously permitted license areas in this area. (Figure 1.2).

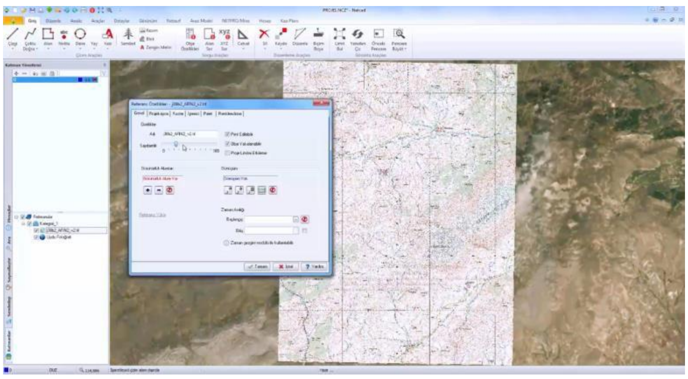

Figure 1.1: Adding the base data online maps used as project base data to the project.

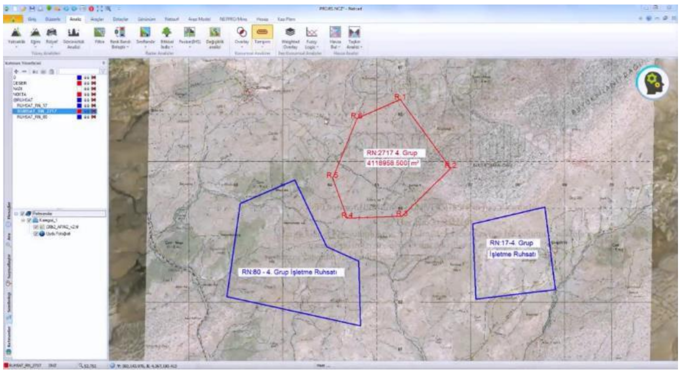

Figure 1.2: Mining license areas.

Buffer zone analyzes of mining license areas have been created and it is ensured that the boundary relationship between license limits is revealed. (Figure 1.3).

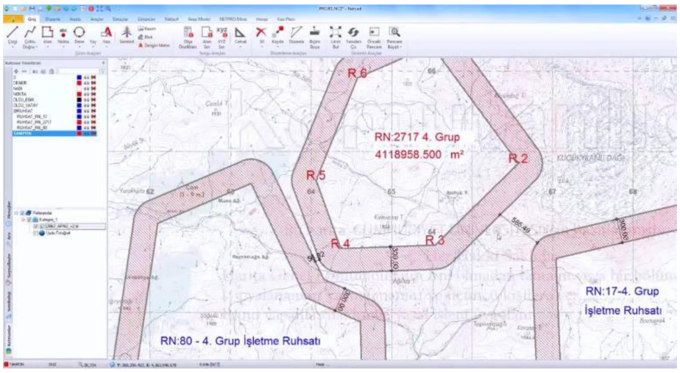

Figure 1.3: Establishment of buffer zones of mining license areas.

1.3 Construction of Digital Terrain Model for Exploration and Production Property

The digital terrain model for the region covering the study area was created by using the elevation data of the region where the activities are carried out, and the contour lines was drawn (Figure 1.4).

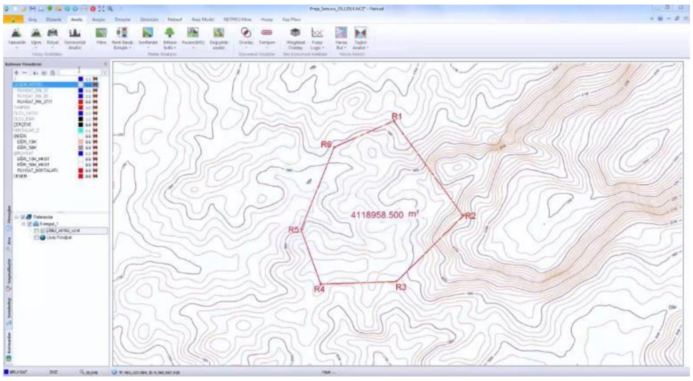

Figure 1.4: Production of digital terrain model of the region where license areas are located and drawing the contour lines.

1.4 Surface (Height, Slope), Landslide and Hydrology Analysis of the Exploration and Production Area

Height analysis was carried out on the digital terrain model of the study area and height changes of the region were shown with thematic intervals. (Figure 1.5). Thus, the interpretation of the height change is facilitated for the area where mining activities are carried out.

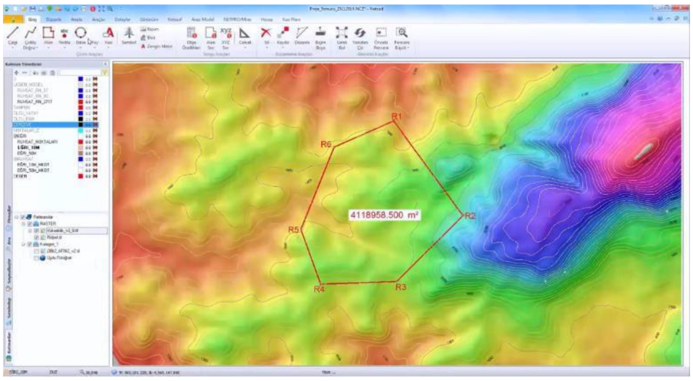

Figure 1.5: Elevation map of the region where license areas are located.

In order to create slope index maps, which is another surface analysis, the digital terrain model was used and the slope changes in the region were revealed in a thematic structure. (Figure 1.6).

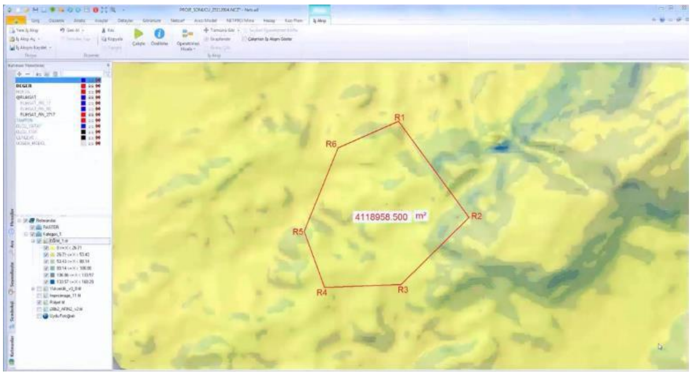

Figure 1.6: Slope index map of the region where license areas are located.

Landslide susceptibility of the license area was analyzed by considering data such as elevation, topographic slope, topographic wetness index (TWI), lithology, sediment carrying capacity index (LS), abrasive power index of a river (SPI) and normalized difference vegetation index (NDVI) with the use of Modified Analytic Hierarchy Process (mAHP) method. (Figure 1.7.1- 1.7.2).

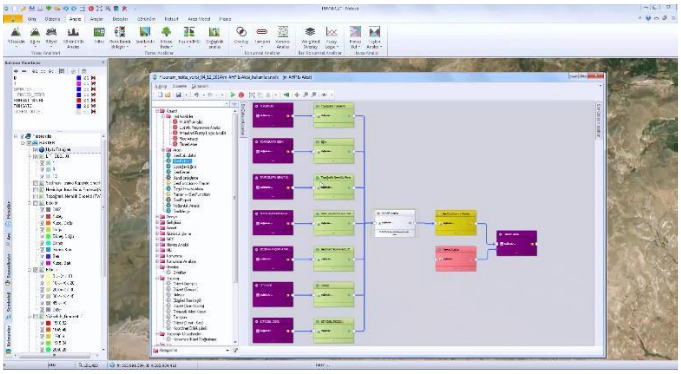

Figure 1.7.1: Modified Analytic Hierarchy Process (mAHP); input data as elevation, topographic slope, topographic wetness index (TWI), lithology, sediment carrying capacity index (LS), abrasive power index of a river (SPI) and normalized difference vegetation index (NDVI).

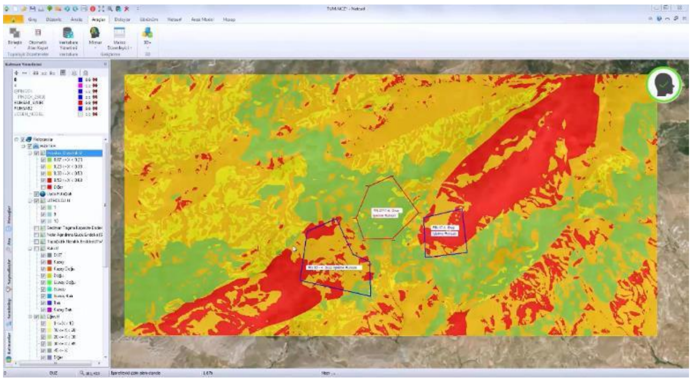

Figure 1.7.2: Landslide susceptibility map of the region where license areas are located.

Basin modeling, determination of precipitation areas and flood flow rate calculations were performed for the estimation of hydrological risks in the license area and the possible flood risks and their limits were determined in this area during the operation period. (Figure 1.8.1-1.8.2-1.8.3).

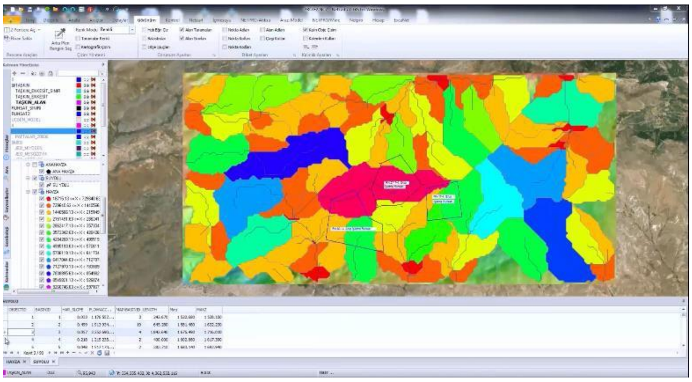

Figure 1.8.1: Basin boundary map of the region where license areas are located.

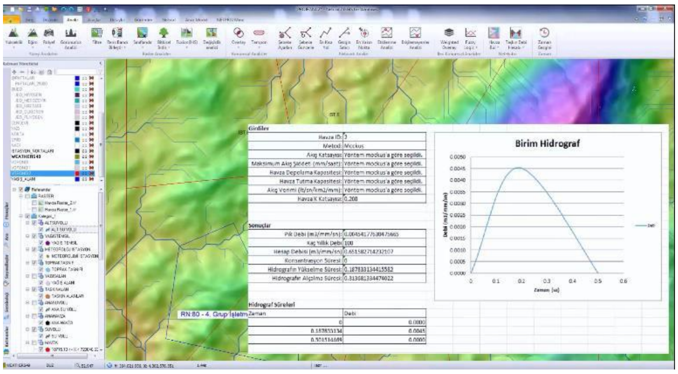

Figure 1.8.2: Flood flow rate calculation of the region where license areas are located.

Figure 1.8.3: Flood susceptibility map of the region where license areas are located.

1.5 Project Output Procedures in Accordance with Institution Standards for Licensing and Analysis Projects

Project outputs were prepared by the institutions responsible for the execution of the mining activities in accordance with the standards set for the project outputs (Figure 1.9).

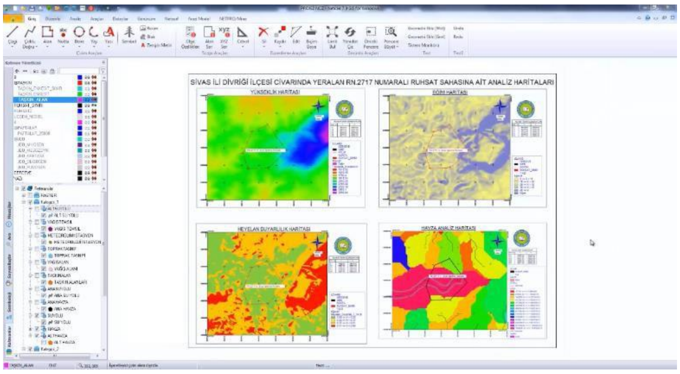

Figure 1.9: Preparing the project outputs at institution standards with the help of output templates.

2 MINERAL RESERVE CALCULATIONS

2.1 Constructing of Annual Production Maps

Existing and planned production benches for the working area were formed by digitizing declared production maps, appropriately scaled and showing the production rate for the next year, from current raster map with coordinates (Figure 2.1).

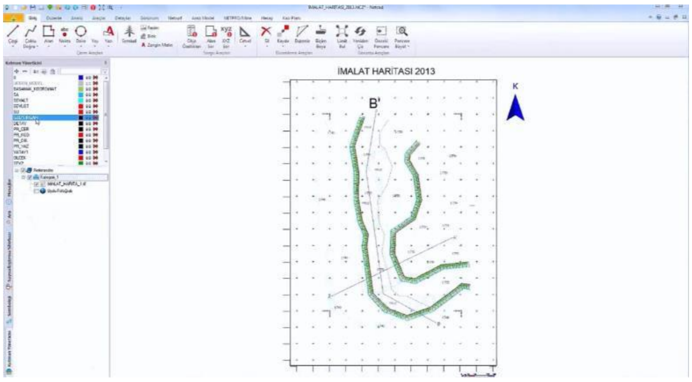

Figure 2.1: Current state of mining.

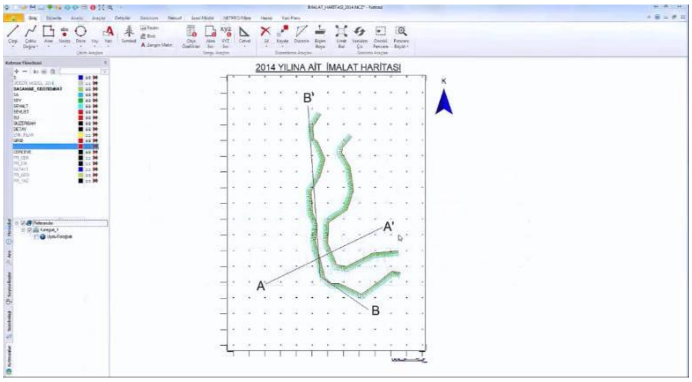

Figure 2.2: Post-production mining production map.

2.2 Preparing Production Cross-Sections

Cross-section operations were carried out along with the same section line through the projects showing the current and post-production status of the area where the mining activities are implemented.

The mining area could be shown by drawing the latitudinal and longitudinal sections created after the cross-sectioning operations.

2.3 Volume Calculation for the Production Area

The annual planned mining production volume is calculated by using the latitudinal and longitudinal cross-sections after cross-sectioning operation (Figure 2.5). The table formed after the volume calculation includes the excavation, filling and cumulative values at the defined intervals along the section line.

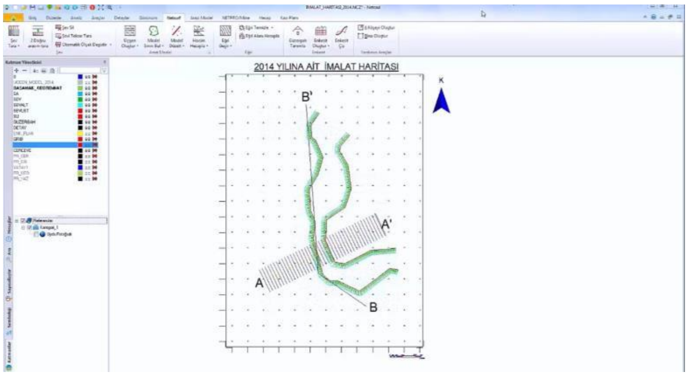

Figure 2.3: Section of the mining production map.

Figure 2.4: Drawing of the cross-sections taken on the mining production maps.

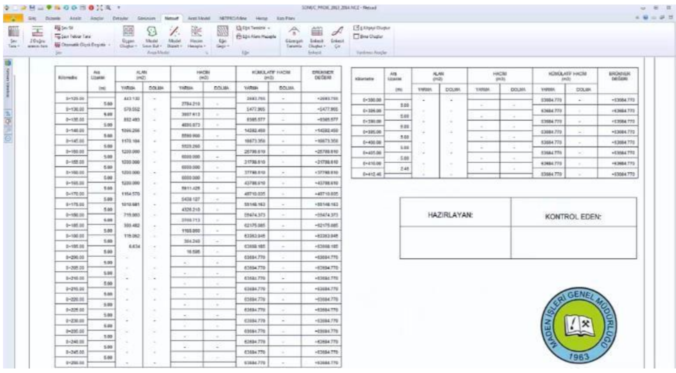

Figure 2.5: Volume calculation of the annual planned mining production.

2.4 Project Output Operations in accordance with Institution Standards for Production Line

Output templates based on the standards determined for the project outputs are formed by MIGEM and project outputs for the production panel are obtained (Figure 2.6).

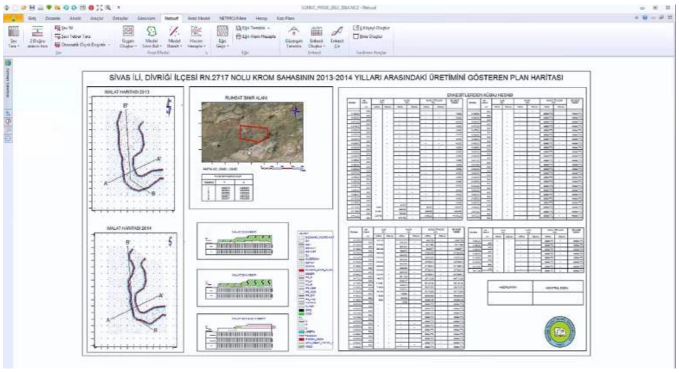

Figure 2.6: Project outputs of the annual planned mine production.

3 OREBODY MODELLING

3.1 Data Entry and Evaluation of the Data

Block modelling and geostatistical estimation was performed with the evaluation of drill hole data.

Geometrical information (hole id, coordinates, dip, azimuth, rake, depth) and attribute data (sample assay values) for the drill holes in the study area are integrated into the project.

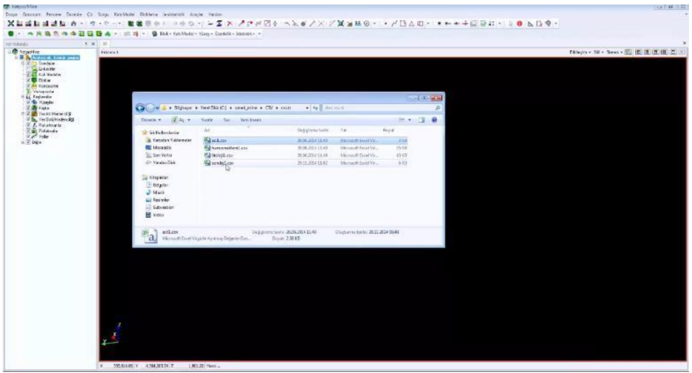

Figure 3.1: Constructing the project file and transferring the drill hole information and data.

Different color, label and geological screening definitions were made for the seam/lithology levels intersected along drilling in order to visualize the drill holes which were transferred to the project file.

Project metrics were determined by calculating statistics for sample length and attribute values of the drillings transferred to the project. Statistics was calculated by selecting attribute and lithology/seam for each drill hole and all drill holes and the values were used for geostatistical estimation.

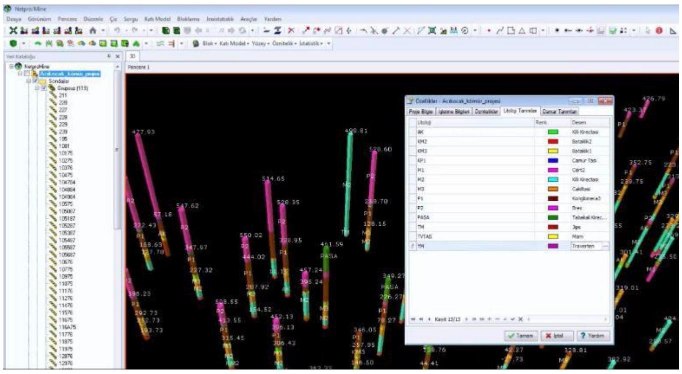

Figure 3.2: Visualization of drill holes on a 3-dimensional screen.

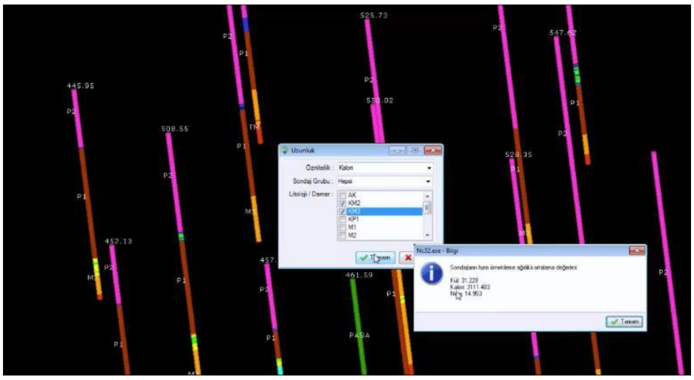

Figure 3.3: Statistical analysis of the drillings.

3.2 Preparing the Drill Hole Log Reports

After completing the color and scans depending on the geological age scale, the drilling logs were prepared for each drilling based on the institution standards. (Figure 3.4).

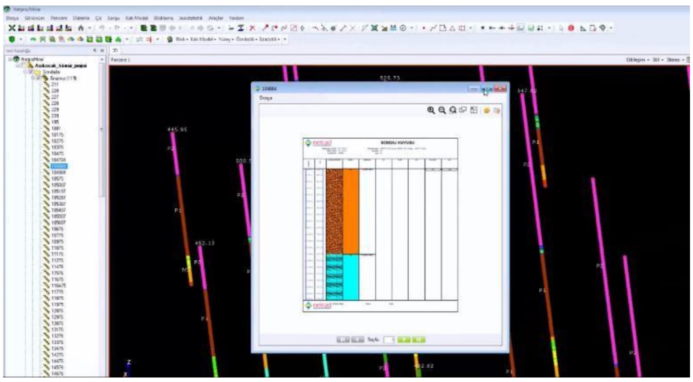

Figure 3.4: Preparing the log reports

3.3 Creating and Modelling Seam/Lithology Surface

Lower, middle and upper surface boundaries of mineralization or other sedimentary units are preferred during the orebody modelling. In the project, lower and upper surfaces were formed by using seam/lithology which corresponds to coal level (Figure 3.5).

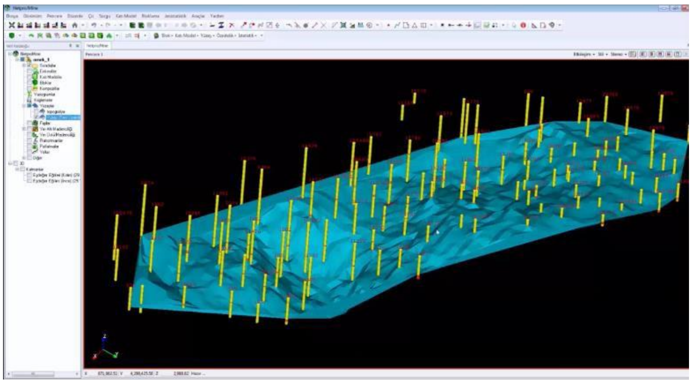

Figure 3.5: Creating the upper surface of the mineralization.

While creating the seam/lithology surface different estimation methods (nearest neighborhood, inverse distance weighting and kriging) can be used and faults can be added to the surface. Area, average elevation and dip for the generated surfaces can be reported.

By using the lower and upper surfaces of the mineralized body (Figure 3.6), the solid model was formed and the volume information of the solid model was obtained (Figure 3.7).

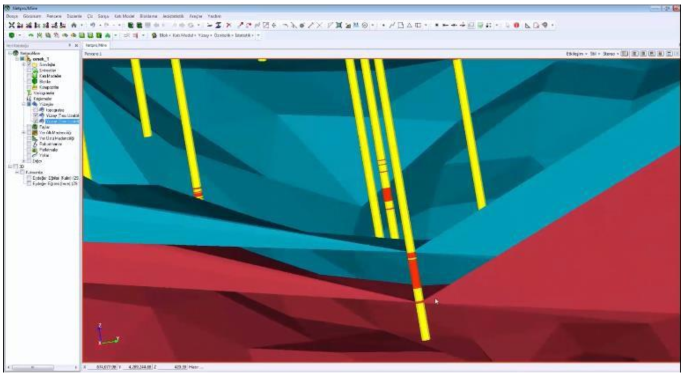

Figure 3.6: Upper and lower surfaces of the mineralization.

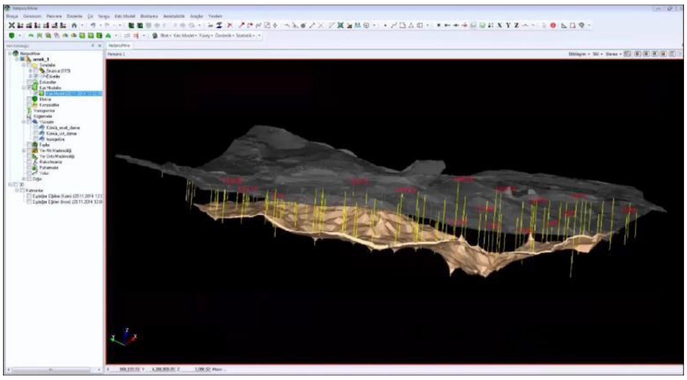

Figure 3.7: The solid model representing the mineralized body.

3.4 Sectioning from Drills and Modelling

Another method used in solid modelling process is construction of the solid model from the cross-sections. In order to create a model with this method, the cross-sections were taken automatically by selecting the drillings that intersected the ore and located approximately in the same direction. (Figure 3.8).

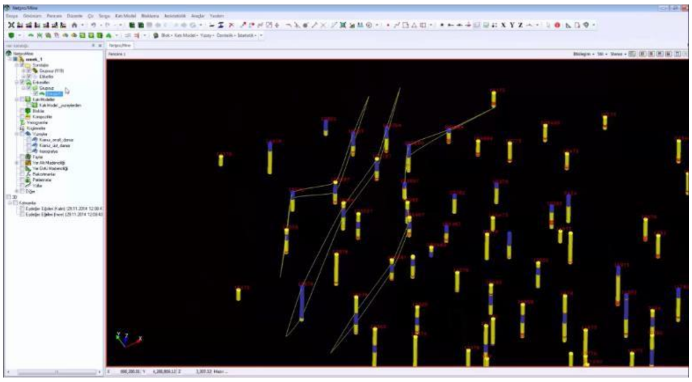

Figure 3.8: Automatic cross-sectioning.

Using the cross-sections, the solid model (Figure 3.9) representing the mineralized body was formed and the volume information of the solid model was obtained.

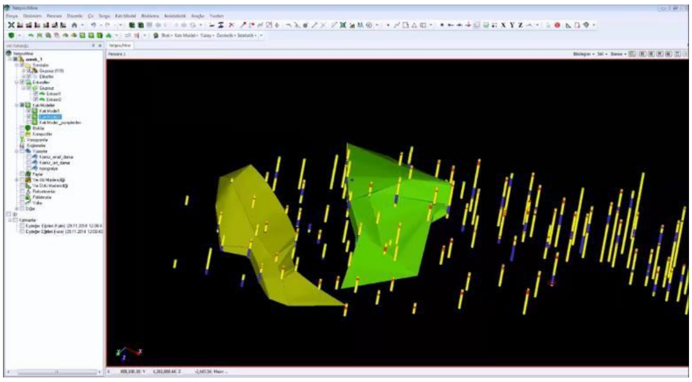

Figure 3.9: Solid models automatically generated from cross-sections.

3.5 Block Modelling and Geostatistical Estimation

The solid model representing the mineralized body was produced and then blocked using appropriate values to estimate attributes for the model (Figure 3.10).

In order to estimate the blocks by using geostatistical methods, a compositing process that converts the samples with different lengths into composite samples with equal lengths was performed (Figure 3.11).

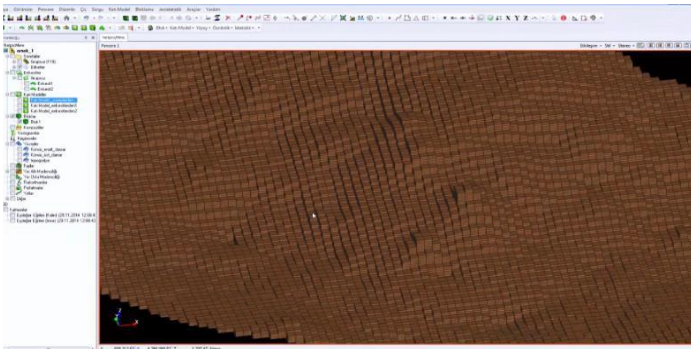

Figure 3.10: Block modelling the solid model.

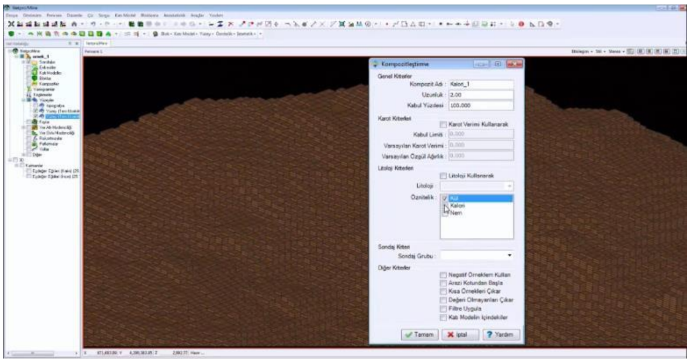

Figure 3.11: Equalization of the sample lengths with the compositing process.

After compositing, the blocks were estimated by using geostatistical methods (variogram, nearest neighbor, inverse distance weighting, kriging) and the attributes of the blocks were mapped in three-dimensional thematic form (Figure 3.12-3.13).

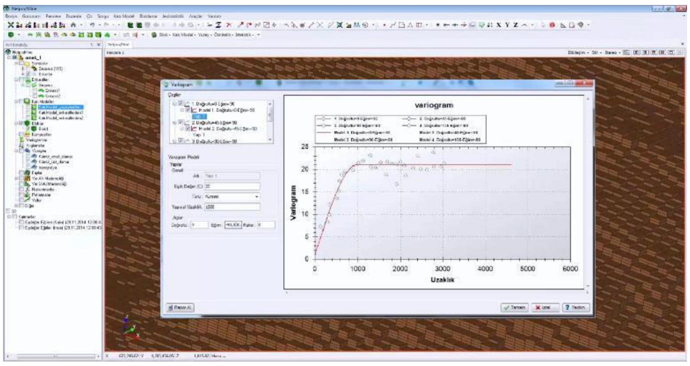

Figure 3.12: Variogram model generated for geostatistical estimation.

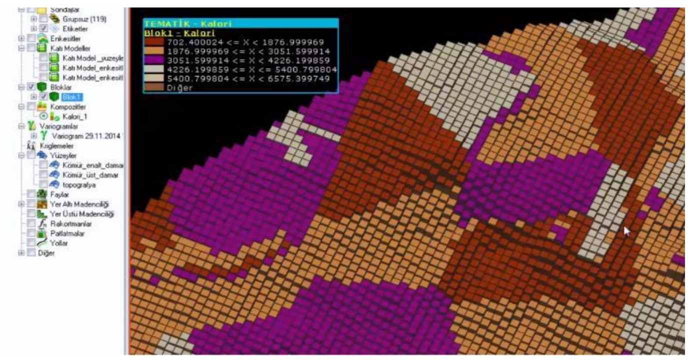

Figure 3.13: Estimated blocks.

3.6 Reporting the Project Properties

After estimation of the blocks, the assigned density and attribute values for each block were reported. In the reports, ore density, attribute, grade-tonnage and volume information were listed. (Figure 3.14).

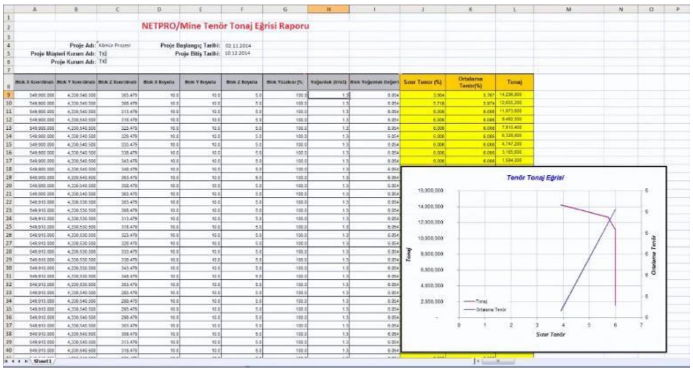

Figure 3.14: Grade-tonnage curve.

4 SURFACE MINE DESIGN

4.1 Defining the License, Mine and Overburden Site Boundaries

In open-pit mine operations, bench design is performed by specifying the top or bottom boundary of the pit/spoil pile.

The top/bottom boundaries in the selected area were digitized and transferred to the project. (Figure 4.1).

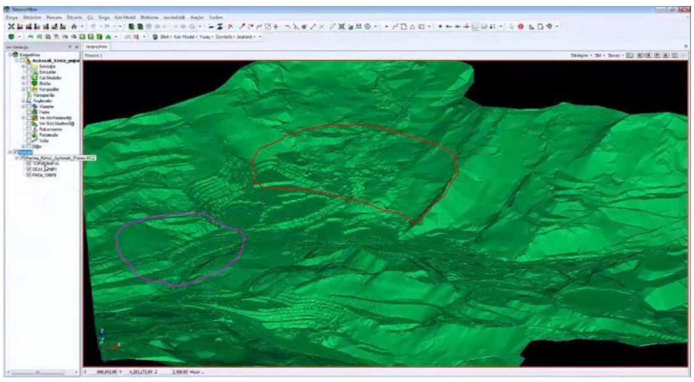

Figure 4.1: The top boundary of the pit/spoil pile and surface topography.

In practice, the bench design has been carried out by using the pit top boundary. Data representing the pit top boundary and topographic surface have been transferred to the open pit tab created for each pit under the surface mining category (Figure 4.2)

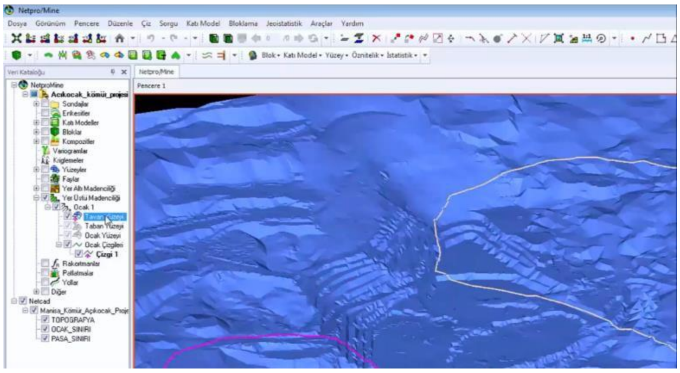

Figure 4.2: Introducing the top boundary and surface of the open pit.

4.2 Bench and Ramp Definitions

Benches were constructed by defining the bench (width, slope, elevation and angle values) for the boundary defined as the pit limit. (Figure 4.3). By using the calculation method and direction determination within the bench definition, it is possible to make the pit design from top to bottom or from bottom to top.

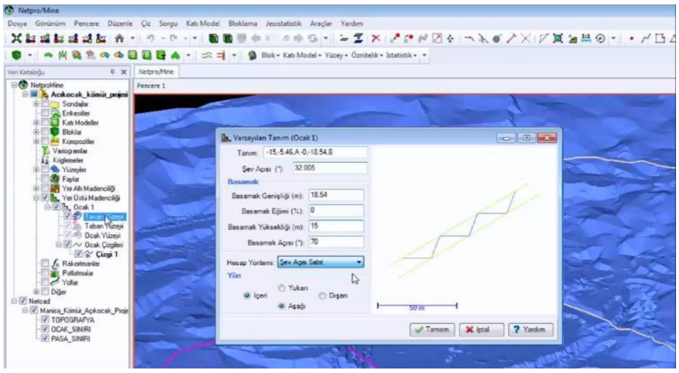

Figure 4.3: Open pit bench design.

The ramp definitions that ensure the transition between the benches are added to the open pit design. After defining the bench and ramp, the benches were created by using automatic bench generation method (Figure 4.4).

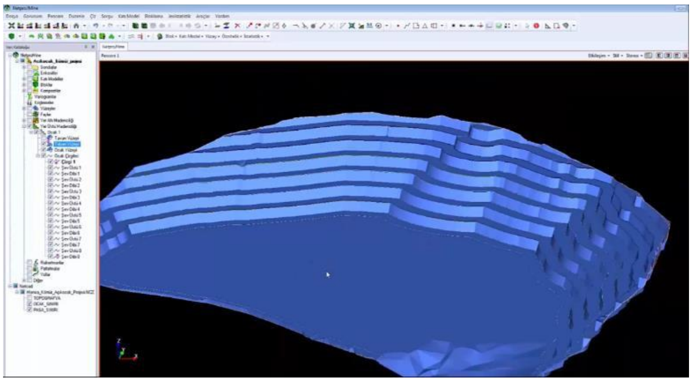

Figure 4.4: View of benches after automatic bench generation method.

4.3 Creating Open Pit Surfaces

Project surfaces were renewed by integrating open pit bench designs with topography and mineralized body (Figure 4.5).

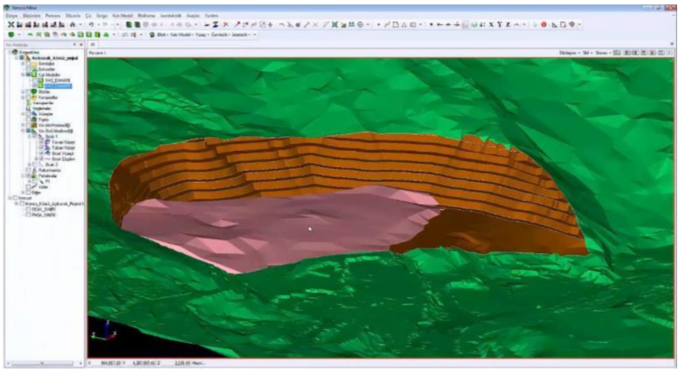

Figure 4.5: The integration of the pit surface with the topographic surface.

Solid model creation and volume calculation were carried out between the elevations for the bench that is to be exploited within the pit. The model was blocked and mineralization information was obtained (Figure 4.6).

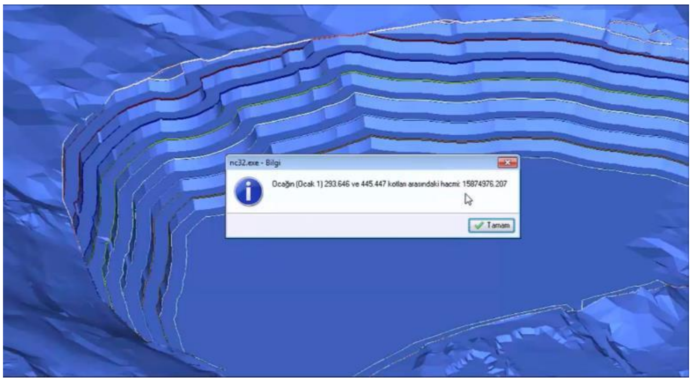

Figure 4.6: Volume calculation between open pit bench elevations.

Waste pile was designed in a similar way to the pit design (Figure 4.7).

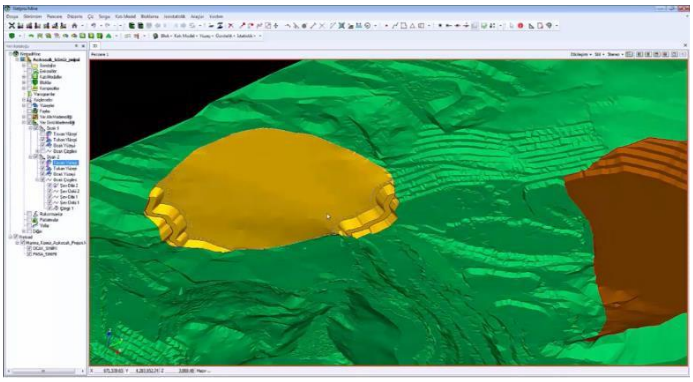

Figure 4.7: Waste pile design.

4.4 Blasting Design, Environmental Impact Assessment and Reporting

After the open pit design, blasting pattern was designed, the blasting evaluations were made according to the blasting method, and the model was combined with the surface model by evaluating the air shock, noise, vibration and flyrock (Figure 4.8).

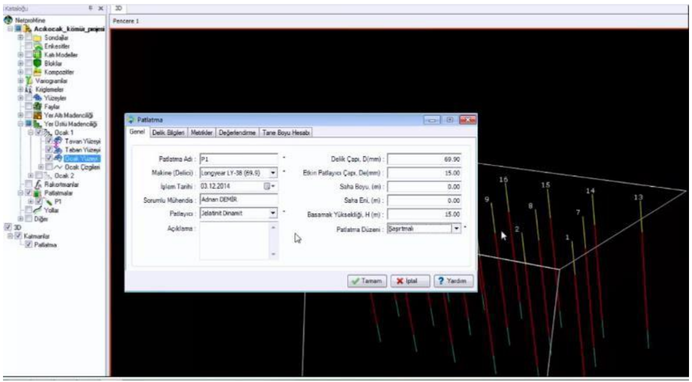

Figure 4.8: Blasting pattern design.

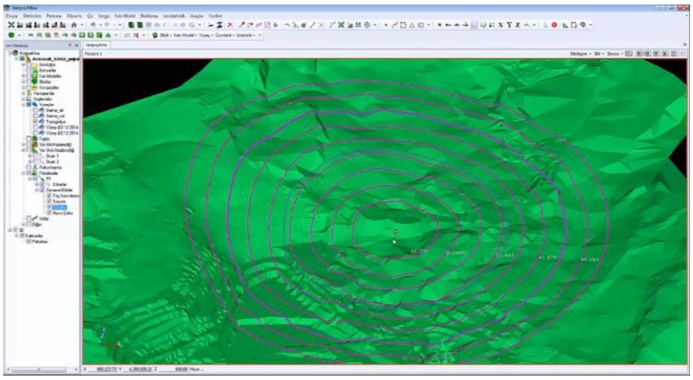

Figure 4.9: Environmental Impact Assessment

Final report for blasting was prepared and blast hole information and metrics were obtained; then all results were prepared in accordance with the standards (Figure 4.10).

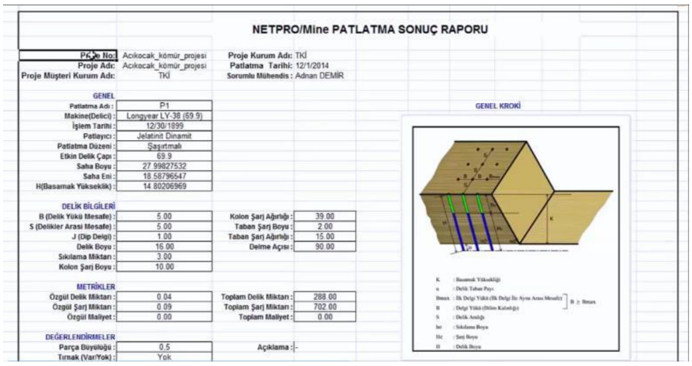

Figure 4.10: Final report for blasting.

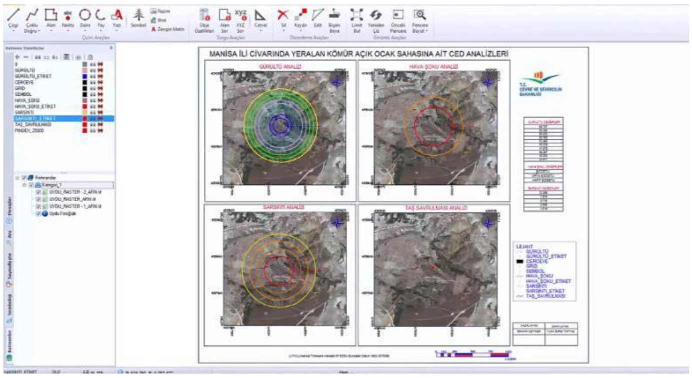

Figure 4.11: Analysis results of the Environmental Impact Assessment.

4.5 Road Design for the Pit/Spoil Pile

Road design was created using horizontal and vertical platform parameter values to ensure connection between the pit and pit/spoil pile and project processes within the scope of rehabilitation were performed. (Figure 4.12-4.13). After the road design, the cut/fill rate was calculated and all details of the road were reported.

Figure 4.12: Open pit road design.

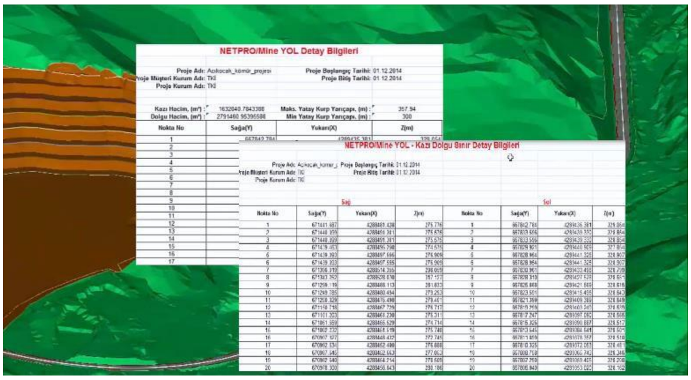

Figure 4.13: Reports of the cut/fill rate for pit/spoil pile road design.

5 UNDERGROUND GALLERY DESIGN

5.1 Designing Underground Production Plan

Galleries appropriate for the ore production plan in underground mining were designed and the gallery installation and transportation systems were integrated into the project.

5.2 Gallery Creation and Visualization

In the scope of the underground production plan galleries were designed by taking into account the profile, type, condition and support properties and by defining the necessary parameters related to the ventilation calculation of the galleries (Figure 5.1).

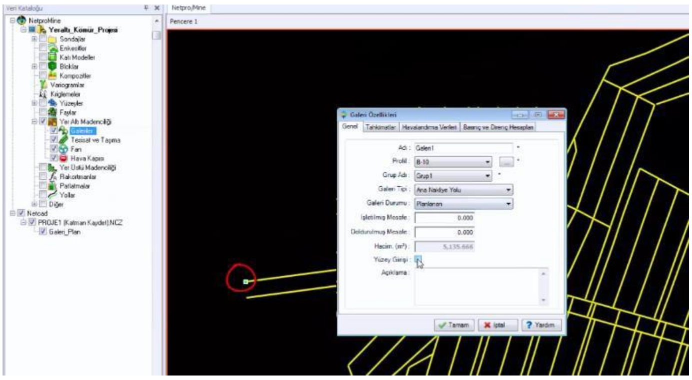

Figure 5.1: Adding a gallery and defining the parameters.

The gallery was visualized in three-dimensional plane according to the selected profile type and its relationship with the production area for the orebody model was shown (Figure 5.2).

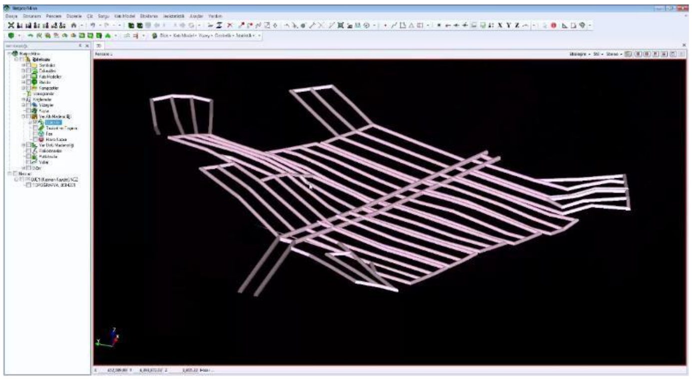

Figure 5.2: Visualization of galleries in 3D.

5.3 Adding Installation and Transportation Systems to the Galleries

The components for both installation (water, electricity, compressed air, etc.) and transportation systems and also the fan and ventilation door were added to the galleries (Figure 5.3).

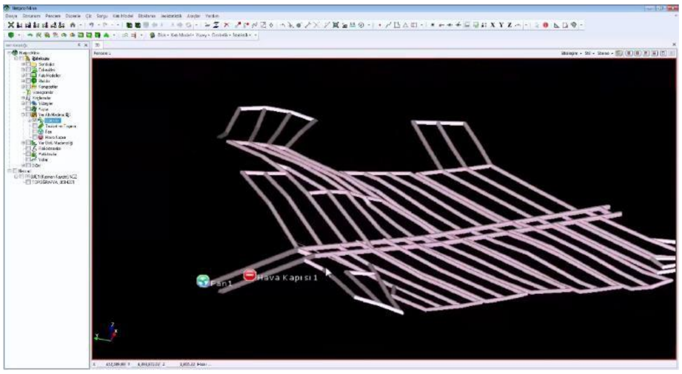

Figure 5.3: Adding the components of installation and transportation systems to the galleries.

5.4 Underground Design Visualization and Reporting

The components added in the underground design such as gallery, installation and transportation systems, fans and ventilation door are visualized in a grid (Figures 5.4-5.7).

Project metrics were calculated by preparing reports for design elements.

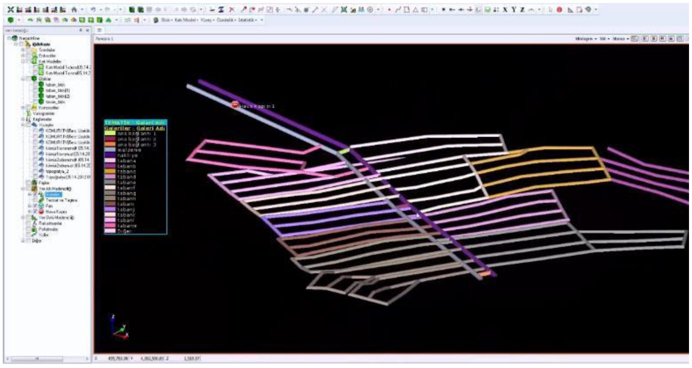

Figure 5.4: Preparing the thematic based on gallery attributes.

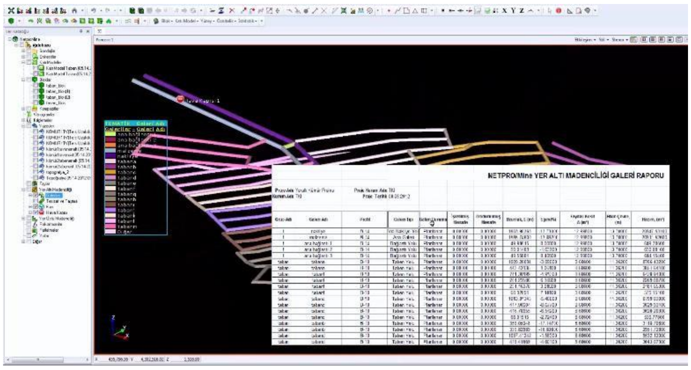

Figure 5.5: The report for the underground gallery and other elements.

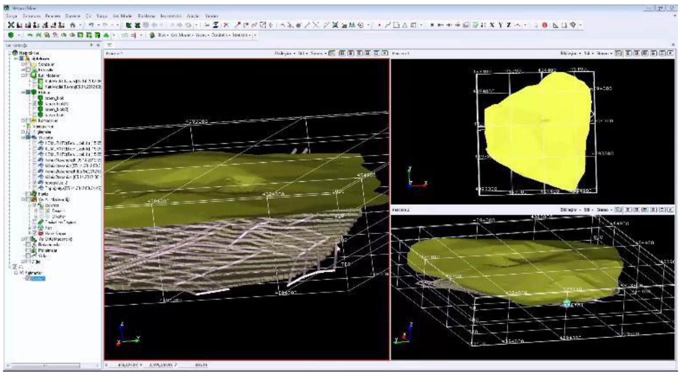

Figure 5.6: Grid display of underground gallery, topography and orebody relationship.

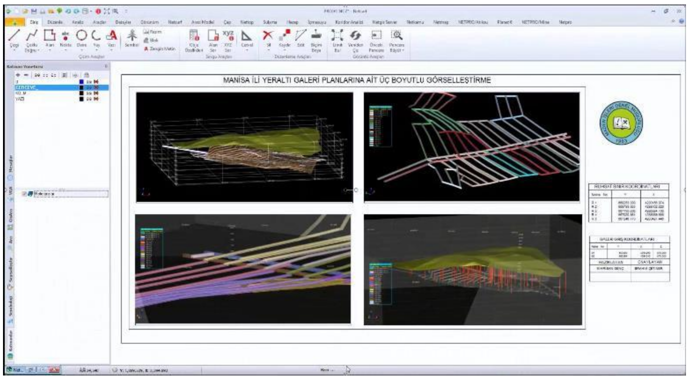

Figure 5.7: Project outputs of underground gallery design.

6 CONCLUSIONS

First of all, mining practices are of great importance because they directly affect human life. The sad accidents happened in recent times in our country's mines have shown us how important the right design of mining projects should be. Another important issue, such as human life, is that mines are non-renewable and inconceivable properties. For future generations, mineral resources should be used at the greatest benefit and in a sustainable way for the benefit of society.

In our country, the most important reason for the occurrence of many occupational work accidents in the mining sector is that our mines are not designed in accordance with the principles of science and technology. Modern mining science and technology requires to optimize the pit before the extraction of the mines, to model the orebody in 3 dimensions, to estimate the reserve, to determine the mining method (surface or underground) and to plan the production.