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Using ArcGIS for Landslide “Umka” 3D Visualization

UROŠ ĐURIĆ[1], BILJANA ABOLMASOV[1], RADMILA PAVLOVIĆ[1] & BRANISLAV TRIVIĆ[1]

Abstract. The recent developments in earth sciences software are mostly related to the extension allowing graphical representations of volumes and geological bodies. In this paper, we present a tool for 3D visualization of landslide body using only ArcGIS© software and its 3rd party extensions. The model was built using existing geological surveys, DEMs, borehole logs and site investigation data. The case study chosen to illustrate the method is the Umka landslide (Belgrade, Serbia), an area with relatively simple geology, but with deep seated landslide and with block-translational sliding mechanism.

Key words: landslide, 3D modeling, visualization, ArcGIS, DEM.

Introduction

Over the past two decades a series of new 3D modeling technologies identified as GIS system software have been developed to subsurface characterization, modeling and visualization needs (BONHAM-CARTER, 1994; BURROUGH & MCDONNELL, 1998). Rapid development of computer hardware and software, data base design concepts and expanded information transfer across Internet encourage geoscientist for easer using sophisticated 3D modeling and decision-support system technologies. TURNER (2006) discussed about challenges and trends for geological modeling and visualization. HACK *et al*. (2006) illustrated a number of three and more dimensional modeling examples in geo-engineering. CULSHAW *et al*. (2006) explained a needs for provisioning of digital spatial data for engineering geologist with examples of using those data for 3D modeling and creating fence diagram of Swansea/Port Talbot area. A modern approach to geological surveying and its relevance in the urban environment with examples of the 3D geology of London and the Thames Gateway was presented by FORD *et al*. (2008).

In this paper we presented possibilities of using ArcGIS© for 3D visualization of landslide. A 3D perspective creates a realistic simulation of a project, environment, or critical situation to help a variety of clients plan and prepare for and proactively mitigate potential issues. For modeling and visualization of landslide, we have used 3D Analyst© module and its extension ArcScene©. Module provides advanced visualization, analysis, and surface generation tools. Using this module, we can view large sets of data in three dimensions from multiple viewpoints, query a surface, and create a realistic perspective image that drapes raster and vector data over a surface. ArcScene© allows earth scientists to create both traditional and unconventional three-dimensional displays from real-world data. Figures created from elevation and depth values are commonly used to reveal the earth’s surface and expose its interior. Alternatively, other measures can represent a third dimension of earth-scientific data. For Case Study, we selected landslide “Umka”, most famous, biggest and deepest landslide in Belgrade. Object was to generate Digital elevation models (DEM) of landslide surface, geological units and slip surface, then their visualization as geological block diagram with cross sections, inside ArcGIS software.

Materials and methods

Case study

Large active landslide “Umka” is formed in Neogene marly clay sediments and takes up surface of 1.8 km^2 (Fig. 1, left). Pannonian sediments, silty - clayey massive soft rocks, have dominant role in geologic composition of terrain. Those sediments are: grey marls

[1] Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia. E-mails: djuric@rgf.bg.ac.rs; biljana@rgf.bg.ac.rs; prada@rgf.bg.ac.rs; btrivic@rgf.bg.ac.rs

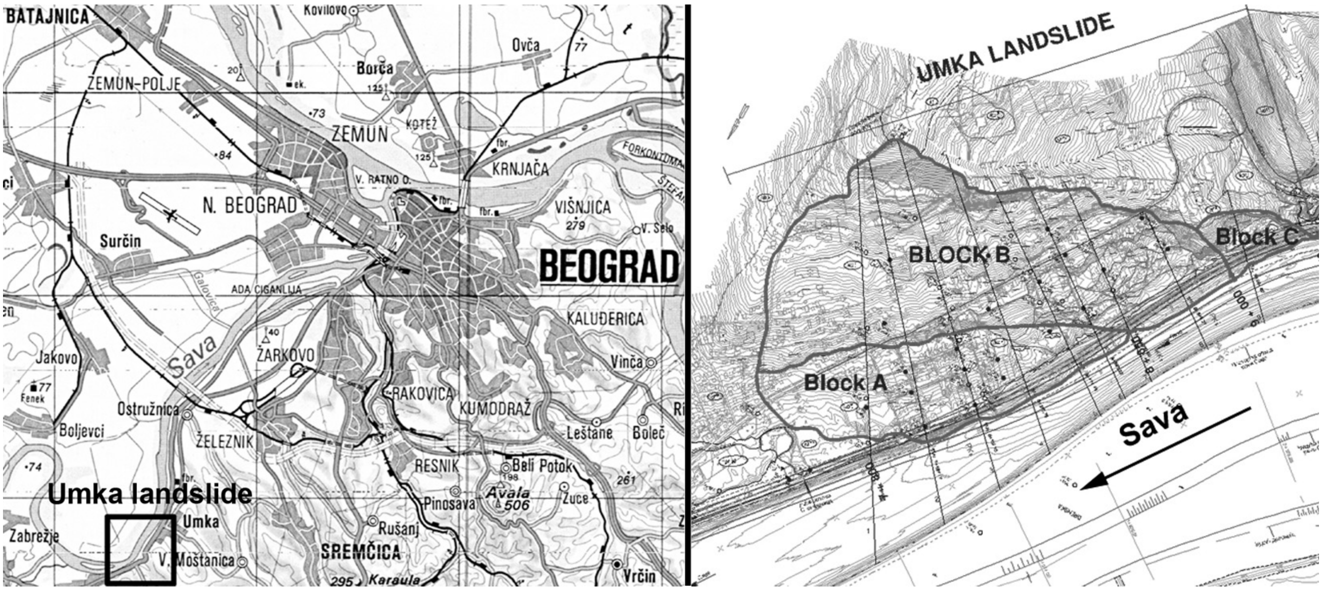

Fig. 1. Position of landslide Umka within Belgrade area (left), Singleouted blocks inside landslide body (right) (The Highway Institute d.o.o., Belgrade, 2005).

(M_3^2L) more than 200 m thick and their upper part formed of weathered marly clays (M_3^2GL) 10–25 m thick. Colluvial deposits (ko) emerged from the gravitational motion of rock masses down the slopes. Material set in motion in the course of time changed its: primary structure, water-borne, and physical mechanical properties. As a rule, colluvium thickness is predisposed by border between more plastic weathered marly clays and hard grey marls, where is obviously deepest sliding surface. Physical mechanical properties of the colluvium vary in a wide range due to the complexity of its composition and susceptibility to external impacts.

This landslide is fan-shaped, with the length along the slope of 900 m, toe width of 1450 m, area of 180 hectares, average depth of 14 m, 7000000 m^3 volume and average terrain gradient of 9°. Upstream landslide part is surrounding the steep frontal scar with the height from 5 to 25 m, whereas downstream landslide part doesn't have a pronounced leap.

The last observations have been made on installed 29 inclinometers, 20 piezometers and 2 exploratory shafts during 2004–2005 yr. According to morphology and sliding mechanism, three blocks have been singled out: A, B, & C (Fig. 1, right).

The length of blocks along the river is 850, 350 and 250 m. During 2005–2006 yr., due to extensive displacements, majority of inclinometers were discontinued. The deepest displacements were recorded in block A - 26 m (Fig. 2), while in blocks B&C landslide depth was 5 to 15 m. Displacements as a rule have translational pattern along slightly inclined parting planes. Displacement speed is increasing during the diminution of Sava river level (GROUP OF AUTHORS, 2005).

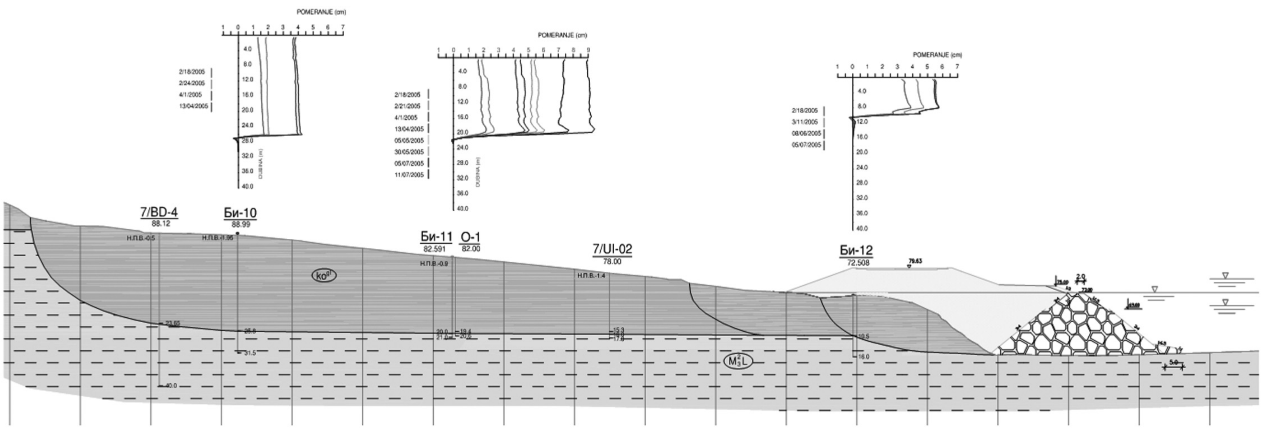

Fig. 2. „Umka“ landslide cross-section, block A (The Highway Institute d.o.o., Belgrade, 2005).

Performing of block diagram and cross sections was completely done inside ArcGIS software. For any 3D landslide interpretation, essential data is derived from borehole logs. In first place, it is crucial to analyze borehole and interpret borehole log. In this paper, we have analyzed data from 28 borehole logs. Used data was obtained from The Highway Institute d.o.o., Belgrade.

Preparing data for modeling landslide

A continuous geological surface can be generated from the formation picks of each landslide borehole using interpolation techniques. A variety of interpolation techniques is available, including using expert's experience: Hand Contouring, Triangular Irregular Network (TIN), Inverse Distance Weighted averaging (IDW), Spline, Trend/Polynomial, Natural Neighbors, Hydrological Correct Interpolation and Kriging.

First, we created table with borehole coordinate and numbers, and then we added surface elevation slip surface elevation, and marl surface elevation fields. Surface elevation and marl elevation was obtained from borehole logs and slip surface elevation was calculated as borehole surface elevation minus depth to slip surface. ESRI point shapefile was created by obtained and calculated data. Example of attribute fields (with first two boreholes) in that shapefile is shown on table 1.

Table 1. Example of attribute fields in borehole point shape file.

FID	Shape	Borh_Id	Surf_elev	Slip_Surf_el	Marl_Surf
0	Point	Bi-24	72,66	68,21	63,11
1	Point	Bi-27	70,2	67,19	63,14

Then, using ArcGIS IDW interpolation tool, we created three DEMs, one for surface (z field was surf_elev), one for slip surface (z field was slip_surf_elev) and one for marl surface (z field Marl_Surf). Surface DEM was cropped by extent of research area and slip surface DEM was cropped by polygon shape that was created by landslide border, which was obtained by previous research (Djurić, 2011).

Creating landslide block diagram

We may say that Geologists have a "passion" for illustratively dissecting the land to create block diagrams. These drawings show a perspective, cutaway view of surface and subsurface geologic features. Using ArcScene, it is possible to generate very creative landslide block diagrams. Essential data for creating block diagrams are DEMs and landslide border polygon shapefile as described by Kennely (2003).

After we loaded all surface DEMs to ArcScene project, the properties for each data layer in an ArcScene project was set to create geologic block diagrams or the other types of three-dimensional data displays discussed in this article. In the Layer Properties dialog box, the Base Heights and Extrusion tabs were used to specify the display of three-dimensional data for all surfaces.

Creating cross sections

After the geological surfaces are generated, cross-sections can be made in any direction. This involves extracting the picks for each surface along the cross-section line. This was done by using ArcMap and 3rd party extension XTools©.

Steps for creating each surface picks was defined by Mei (2008):

- Loading surface layer in ArcMap
- Drawing line in preferred cross section direction using Drawing tool
- Converting graphic line to line feature using XTools Feature Conversions | Convert Graphics to Shapes
- Converting line shape feature to points, using XTools Point to Feature Conversions | Convert Features to Points (with Equidistant points set to 1000)
- Converting feature points to 3D using ArcGIS Convert | Features to 3D, and creating cross_points_surface.shp as output file.
- Adding X, Y and Z values cross_points_surface.shp from surface DEM, using XTools Table Operations | Add X, Y, Z Coordinates tool.
- Repeating steps 5&6 for slip surface and marl surface DEMs
- Joining all surface generated cross_points_X.shp files in one shape file named cross_points_all_picks.shp

Next step was loading cross_points_all_picks.shp into ArcScene, and copying that layer three times inside ArcScene (for each surface). Inside Layer Properties dialog box, the Base Heights and Extrusion tabs were used to specify the display of three-dimensional data for cross section. Process was repeated for second cross section that was normally positioned compared to first cross section.

For creating a 3D display of a geological solid, it was necessary to construct its top and bottom surfaces and the side boundary surface. The top and bottom surfaces of the solid was created by clipping the top and bottom geological surfaces using the extent of the solid; the side boundary surface was created and displayed in the same way as a cross-sections.

Figures 3 shows generated landslide block diagram with surfaces and Figure 4 shows generated landslide cross-sections in form of block diagram, using methods mentioned in this paper.

N represent an attribute. 2D systems represent the world as a collection of data layers, and all conventional GIS, including ArcGIS, use this data model as its base. 2,5D data usually comes in X, Y & Z format, where X & Y are spatial coordinates and Z is sampled attribute representing relative height/elevation (e.g.

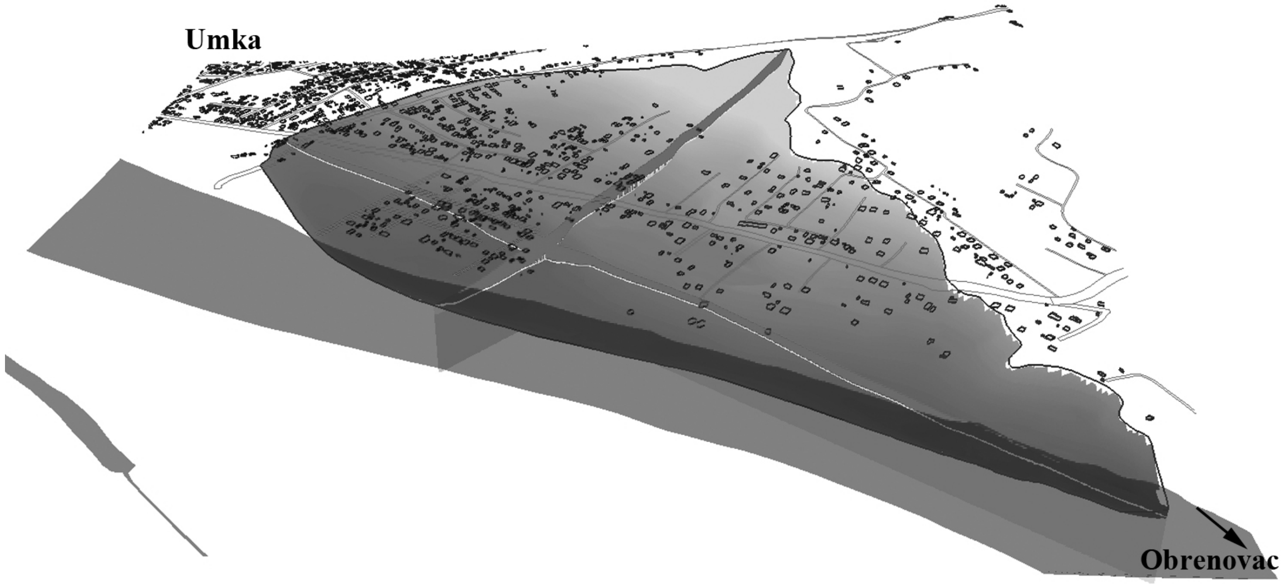

Fig. 3. „Umka"Landslide block diagram with generated surfaces.

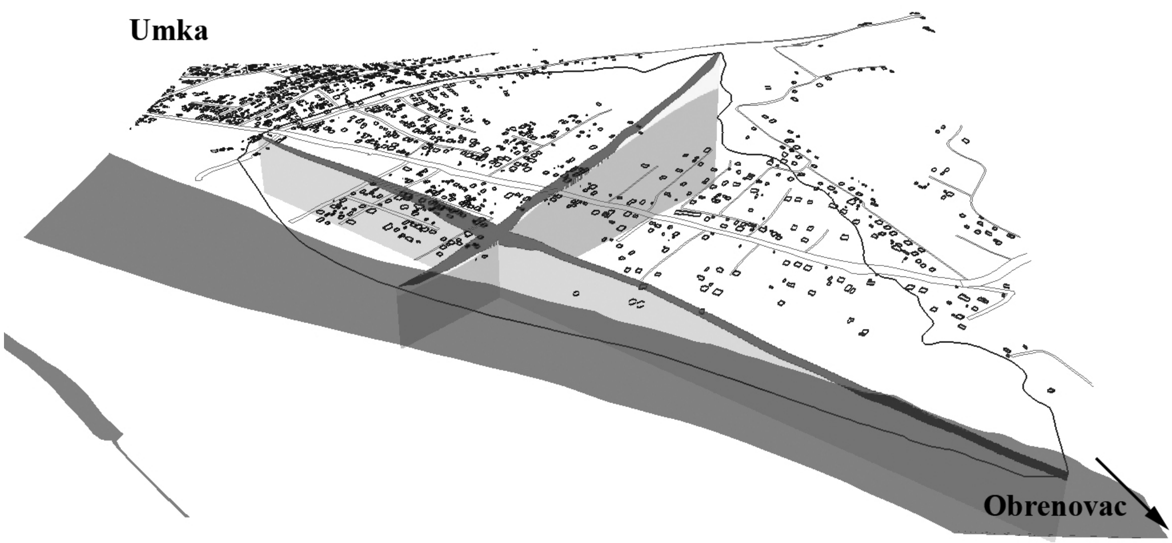

Fig. 4. "Umka"Landslide cross-sections in form of block diagram.

Results and discussion

Strictly speaking, using GIS terminology, the 3D visualization demonstrated in this paper actually represents 2.5D visualization, not a true 3D presentation. In GIS models, 2D data usually comes in X, Y & N form, where X and Y represent spatial coordinates and DEM). DEM is actually matrix of elevations that are considered as 2.5D data. However, they are usually plotted as a DEM surface to be visualized in a 3D perspective drawing. Most important thing in geological modeling is that is not always necessary for surface to be an elevation, it could be: lithological facies, porosity, permeability or some other geological parameter that could be plotted as surface. 3D data usually is represented with X, Y, Z & N, where X, Y & Z are spatial coordinates and N are is an attribute.

3D heterogeneity within a geological unit can be presented only in a true 3D presentation using 3D data. In a 2.5D representation, it is impossible to represent different attributes at two different elevations at the same 2D point (which is a true 3D presentation) and maintain a 2D data model. As a result, the three dimensional heterogeneity within a geological unit cannot be modeled and displayed in ArcGIS. This limits the full use of borehole log data that contain geological attributes measured with x, y and z coordinates MEI (2008).

Conclusion

The figures accompanying this article are just a few examples of how geologist data can be displayed in conditionally 3D with ArcScene. As demonstrated by the surface and subsurface landslide examples, z-values can be derived from elevation values. Alternatively, the z-coordinate can be derived from any measured value. These values can vary continuously and create a surface over which additional data may be draped or can be discrete and cause abrupt changes in z-values at boundaries. The flexibility of assigning z-values from various sources makes ArcScene a powerful tool for anyone who needs to show the quantitative variations in 2,5D data.

Main advantages in this approach of landslide modeling are:

- Analyzing terrain data to determine what can be seen from different observation points,
- Modeling subsurface features such as wells, groundwater, slip surfaces, networks and facilities that could be affected by landslide
- Determining optimum facility placement or resource location for geological investigations,
- Sharing 3D views, animations, and analyses with stakeholders and decision makers,
- Geologist can examine subsurface structures and calculate volumes

3D geological models are also used to complete valuable calculations for use in geotechnics. Many times, geotechnics engineers are unable to calculate precise volume of landslide body, which is very important for 3D slope stability analysis, and therefore it is important to have software that can calculate these variables. With surface layers performed by methods mentioned in this paper, it is easy to calculate exact volume of landslide, converting surface and slip surface to TINs and then using Tin difference tool inside ArcGIS© for precise volume calculation.

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