DETAILED ANALYSIS OF GEORELIEF DEVELOPMNET IN THE LAKE MOST SURROUNDINGS

[a]JAN PACINA, KAMIL NOVÁK, VLADIMÍR BRŮNA, JAN POPELKA

Faculty of the Environment, UJEP, Dělnická 21, 434 00 Most
email: [a]jan.pacina@ujep.cz

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Abstract: There has been a dramatic change of the georelief in the area of the Lake Most (North-West Bohemia, the Czech Republic) caused by the open-cast mining activity which has destroyed even the royal town Most. In the georelief development analysis was used the aerial imagery from the year 1953 and 2008, maps of the 3rd Military Survey reambulated in the year 1938 and State maps 1:500 from the years 1953, 1972 and 1981. Digital terrain models (DTM) and digital surface models (DSM) of the historical georelief were created for visualization and analysis. With the usage of DTM's and DSM's are we able to perform more analysis showing in detail the georelief changes caused by the open-cast mining activity.

Keywords: Lake Most, georelief change, digital terrain models, digital surface models.

1 INTRODUCTION

Landscape influenced by open-cast mining is very typical for the North-West part of the Czech Republic. The mining activity has a great impact on the landscape structure, land-use development, shape of georelief and human life in general. In this paper we would like to focus on a very significant example of landscape transfiguration caused by the open-cast mining. The royal town Most established in the 13th century was destroyed together with the surrounding villages as over 100 million tons of brown coal was mined in this area. The mining itself started in 1950's and was definitely stopped in the year 1999. In the year 2008 started the hydrical reclamation of the depleted mine – which means that the mine was over-flooded into a form of a lake.

Fig. 1 Landscape change in the Lake Most surroundings, PKÚ (2013), FM (2013).

Reconstruction of the georelief in different time periods within this locality is very important for understanding of the total landscape change in this region. The shape of the georelief may be reconstructed from the altimetry information contained in old maps or by processing old aerial photographs by the standard ways of photogrammetry. The resulting Digital Terrain Models (DTM) should be offered to the scientific society and the wide public. This is done by publishing the data through a Geographic information system (GIS) of this locality and the GIS Internet technologies.

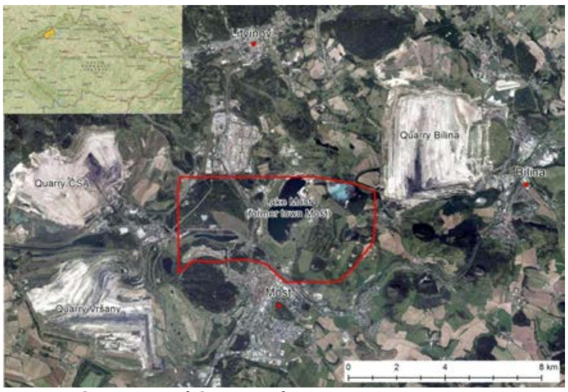

Fig. 2 Delimitation of the area of interest

2 INPUT DATA

The georelief can be reconstructed from two relevant data sources:

- maps with relevant altimetry information,
- photogrammetrically processed aerial imagery.

These two data sources require very different handling and processing. The old maps contains contour lines that have to be hand-digitized and further more interpolated into a form of an elevation GRID (DTM) using a suitable interpolation algorithm. The DTM represents the "bare ground" – a terrain model without any artificial objects (buildings) and vegetation. The Digital Surface Model (DSM) derived from the processed aerial imagery includes on the other hand all the buildings and vegetations – and we need to incorporate this fact into the analyses.

The newest method of LIDAR (LIght Detection And Ranging) allows a precise laser scanning of the surface offering a comprehensive elevation data with high points density and optionally containing the vegetation and buildings or not.

2.1 Old maps

The elevation information is in old maps represented in a very different way. In the very old maps is the georelief described by drawn hills, later on by hachure or similar types of visualization. The terrain reconstruction from these representations is in many cases impossible, or very problematic as shown by Vichrova (2012).

The oldest maps within our area of interest, with terrain represented by contour lines (with interval 5 to 20m), are the 3rd Military Survey maps reambulated in 1930'. The 3rd Military Survey was performed in 1868 based on the cadastral maps. Compared to the 2nd Military Survey is the hypsography described not only by hachure, but as well by contour lines and elevation points. The results of mapping are so called topographical sections (1:25 000), special maps (1:75 000) and general maps (1:200 000). The topographical sections were used in this project.

The other very important source of data for georelief reconstruction is the Derived state map in the scale 1:5000 (SMO-5). The whole Czech Republic is since the year 1950 covered by SMO-5 maps. This map is not based on direct field measurements, but is derived from existing map sources. Elevation data are in these maps presented in the form of contour lines, elevation points and technical hachure. The base contour interval is 1 meter, 2 m or 5 m in addiction to base map elevation data (Veverka, 2004).

In the State regional archive in Most were found complete SMO-5 map series fully covering the period of active coal mining in the area of interest. Altogether 36 map sheets were scanned on the special map scanner and further processed.

Very important part of the workflow is to process the old maps. All the maps have to be georeferenced and the contour lines representing the elevation information hand-digitized. Several methods were used for the map georeferencing as different maps require different treatment. The Czech national S-JTSK coordinate system (Georepository, 2013) is used for all mentioned maps.

Maps of the 3rd Military Survey were processed using the spline transformation implemented in ArcGIS. The spline transformation is a true rubber sheeting method and is optimized for local accuracy, but not global accuracy. It is based on a spline function - a piecewise polynomial that maintains continuity and smoothness between adjacent polynomials (ESRI 2013). The transformation accuracy has been visually tested with the MapAnalyst (Jenny and Weber 2010) application by applying a regular square network on the transformed data. Old maps processing is in detail described in Cajthaml (2012).

The georeference of SMO-5 maps was performed based on the knowledge of the map corner coordinates. The georeferenced maps are stored in an ESRI file geodabase and visualized by mosaic dataset which is used to mask the map frame information producing a seamless map.

On Fig. 4 are presented processed maps of the 3rd Military Survey and SMO-5 with digitized contour lines and DTM's derived using methods described in Chapter 3. Note that the DTM derived from SMO-5 maps has higher resolution thanks to 1m contour lines.

2.2 Aerial imagery

Aerial imagery is the second alternative of georelief reconstruction as the new methods of digital photogrammetry deliver relatively fast way of producing DSM of large areas. Aerial images from the year 1953 and 2008 were processed in this area of interest. The aerial images from 1953 taken shortly after the WWII are showing the landscape partly affected by heavy industry and open-cast mining activity. The images from 2008 are showing the Lake Most shortly before the over-flooding process.

The problem with processing old aerial imagery is the dramatic landscape change in this region. The workflow requires definition of Ground Control Points to "georeference" the aerial images but in this type of an area it is problematic to define them.

Aerial photographs have been processed in the standard way of photogrammetry using the Leica Photogrammetric Suite. For detail description of aerial image processing in this region, see Elznicová (2008) and Weiss (2011).

The aerial imagery from the year 1953 is not of a very good visual quality. The images are noisy, scratched, and affected by the contemporary technology of creation – this affects the automatic DSM creation from aerial images. Nevertheless is this datasource a very important part of this project.

2.3 LIDAR data

A very precise elevation data are available for the year 2012 created using the LIDAR method. The Digital Terrain Model of the Czech Republic of the 4th generation (DMR 4G) represents a picture of natural or by human activity modified terrain surface in digital form as heights of discrete points with X,Y, H coordinates in irregular triangle network (TIN). H means the altitude in the Baltic Vertical Datum - After Adjustment with total standard error of 0.3 m of height in the bare terrain and 1 m in forested terrain. (ČÚZK, 2013)

3 GEORELIEF RECONSTRUCTION

The data sources defined in chapter 2 are offering quality inputs for georelief reconstruction and analysis. Each of the data sets has to be processed in a different way respecting the nature of the data.

3.1 Contour lines interpolation

Various interpolation algorithms are implemented in the common GIS products. Each landscape type requires a specific interpolation method to obtain quality DTM (see Jedlička, 2009). For purposes of this project were tested interpolation algorithms implemented in GIS GRASS and ArcGIS. Small part of the area of interest was used for the testing purposes.

The Regularized Spline under Tension (RST) was tested in the GIS GRASS environment as it was suggested to be the most suitable method. The theory for RST computation is described for example in Cebecauer et al. (2002) and Neteler and Mitasova (2007). The RST interpolation is driven by several parameters, the main are tension and smooth. The tension parameter sets the toughness of interpolated surface for thin steel plate to a rubber membrane. With smooth parameter set to zero is the interpolated surface passing exactly through the input data. The smooths and tension parameters were experimentally tested. All interpolated surfaces had visible artifacts of segmentation used for faster performance of the interpolation. This method was thus evaluated as a not suitable (see Fig. 3).

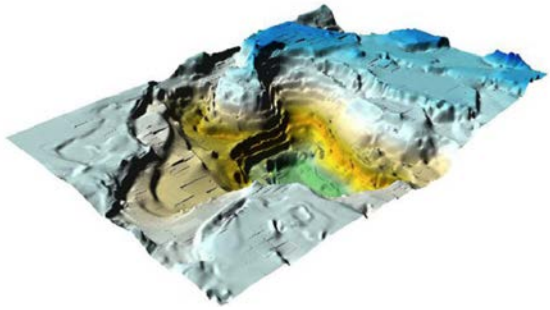

Fig. 3 Segmentation artifacts visible on the DTM interpolated by RST method (GIS GRASS)

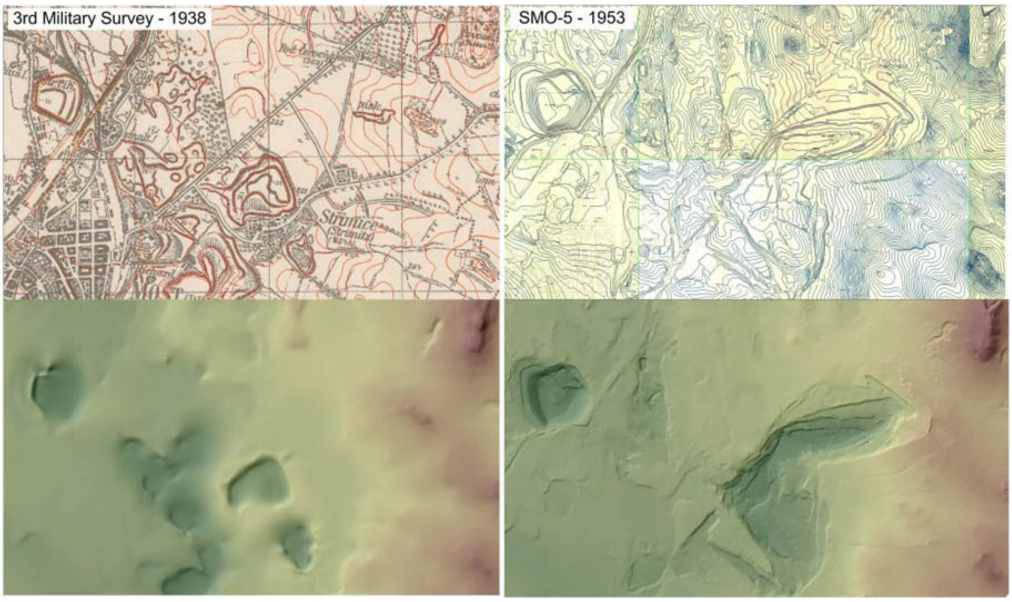

Fig. 4 Digitized contour lines on maps from 1938 and 1953 and the resulting DTM's showing the exactly same area

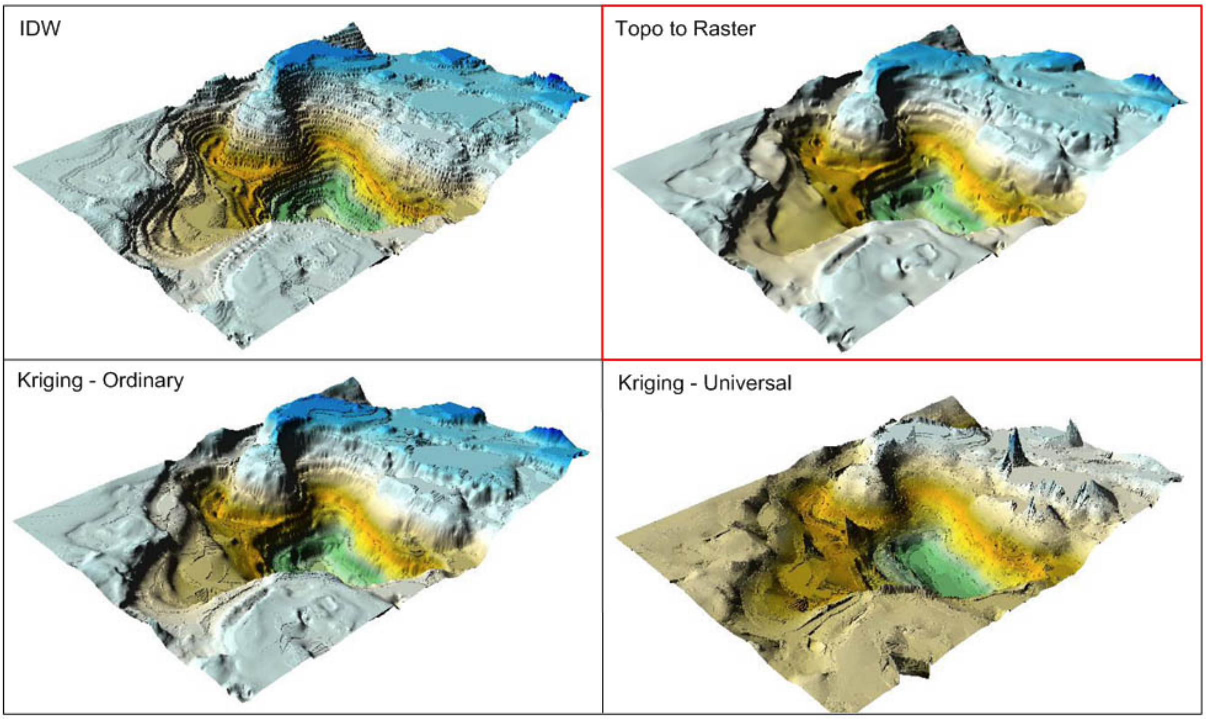

Fig. 5 Interpolations tested in the ArcGIS environment

The following interpolation methods (described in ESRI (2013)) were tested within the ArcGIS with the following results:

- Inverse Distance Weighted (IDW) is producing artificial peaks and pits at the input point's location. The change of the parameter power did not have much effect on the resulting data.
- Kriging – Ordinary and Universal – both interpolation algorithms produced artificially sharp peaks.
- Topo To Raster – produced a natural terrain with no visible interpolation artifacts.

Interpolation examples are presented on Fig. 5.

3.2 Aerial imagery and LIDAR

The DSM's are results of automatic image correlation. This method is used for automatic DSM extraction from aerial images with known orientation parameters with image overlap (60% in our case). The classic ATE module implemented in LPS 2011 was used for the automatic DSM creation. The extracted DSM's are the desired results for historical landscape restoration.

Processing of the LIDAR depends on the data format obtained from the vendor. In our case are the data obtained in the text file in the form of [X, Y, Z] coordinates. These elevation points are imported into GIS and further on converted into DTM (using the function Point to Raster). The resulting dataset is shown on Fig. 6.

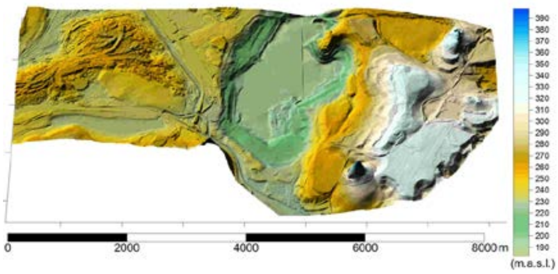

Fig. 6 LIDAR dataset of the Lake Most surroundings

3.3 DTM time-line analysis

All the processed input data were used for DTM and DSM creation and thus we got the following results:

- 1938 – slow start of open-cast mining in the town Most surroundings,
- 1953 – more intense mining, in this year was decided do destroy to old town,
- 1972 and 1981 – the highest mining activity in this area, the town is being mined away,
- 2008 – the mine is depleted and since 1999 is being turned into a hydric recultivation.

The resulting DTM time-line is thus covering the complete DTM development of area of interest. Old maps covering the period before 1938 with usable hypsography does not exist. The created DTM's and DSM are presented on Fig. 8, Fig. 9, Fig. 10, Fig. 11 and Fig. 12. For better understanding of the DTM characteristics are in each model defined four cross-section profiles further visualized by graphs. The detailed cross-section analysis is presented on Fig. 13, Fig. 14, Fig. 15 and Fig. 16. On Fig. 7 is presented the detail of defined area of interest visualized over the 2008 ortho-photo.

Fig. 7 Detail of area of interest (year 2008)

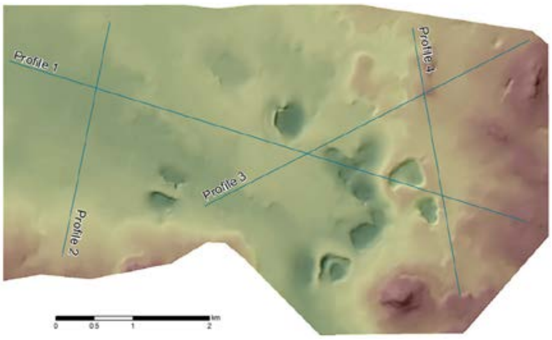

Fig. 8 DTM - year 1938

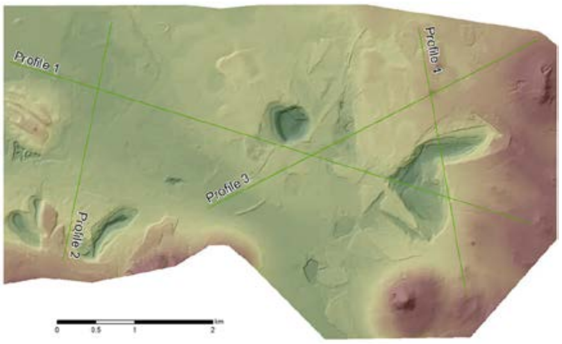

Fig. 9 DTM - 1953

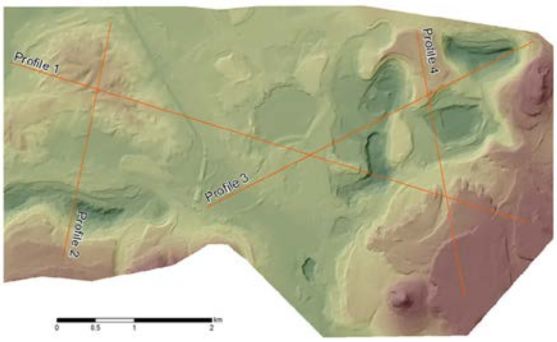

Fig. 10 DTM – 1972

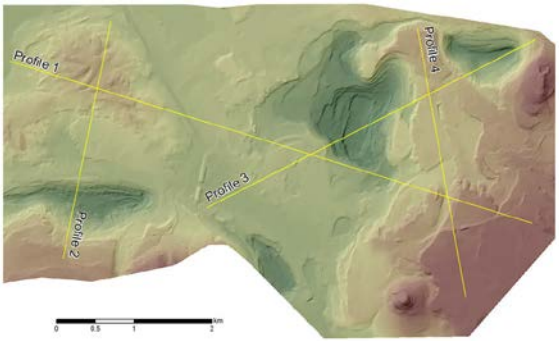

Fig. 11 DTM – 1981

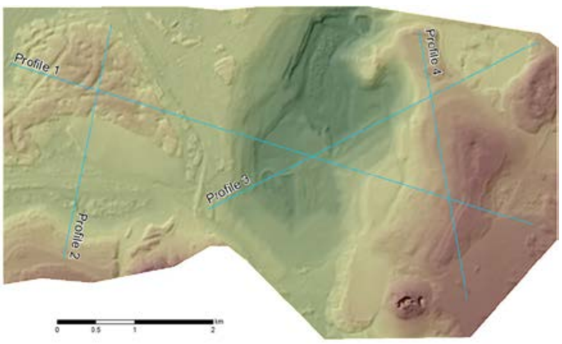

Fig. 12 DSM – 2008

4 CONLUSIONS

A detailed analysis of the area affected by open-cast mining based on data from different time periods are presented in this paper. We used three types of data sources – maps from the 3rd Military survey (year 1938), SMO-5 maps (years 1953, 1973 and 1982), aerial images (year 1953 and 2008) and current LIDAR data.

The elevation data in the form contour lines were extracted from old maps and further interpolated into DTM's. A suitable method for data interpolation was chosen based on performed interpolation tests. The aerial images were processed in a standard way of photogrammetry with DSM's as the resulting elevation grid. For further processing of this area we may consider the usage of aerial images from the year 1938 covering the whole region as well.

Very illustrative analysis of the georelief transfiguration is the profile analysis. Here, we may study the georelief change in detail and we may use the profiles from the all five processed periods. The transect lines were defined in the direction of the major georelief changes.

The resulted DTM's and DSM's have a wide usage in data modeling and may be used in many kinds of applications – visualization, hydrological modelling, recultivation works and much more. All the processed data – maps, aerial photographs and the resulting DTM's and DSM's are available at the university mapserver http://mapserver.ujep.cz as WMS and ArcGIS Server layers. The direct link to the application presenting the data is:
http://mapserver.ujep.cz/Projekty/SZ_Cechy/Jezero_Most_nove/

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Primary Paper Section: A

Secondary Paper Section: D, G, L

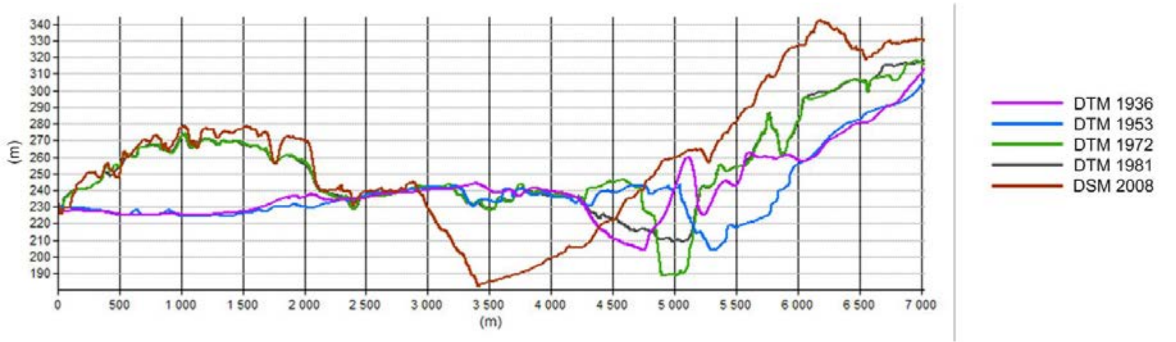

Fig. 13 Analysis of Profile 1

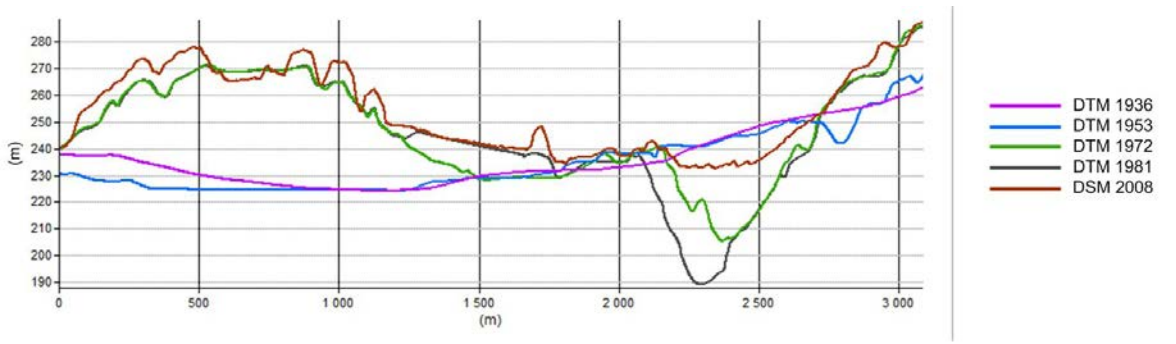

Fig. 14 Analysis of Profile 2

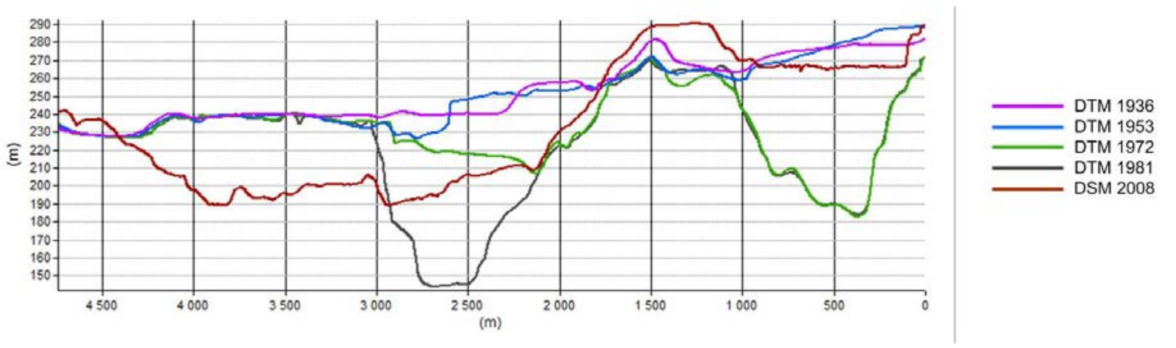

Fig. 15 Analysis of Profile 3

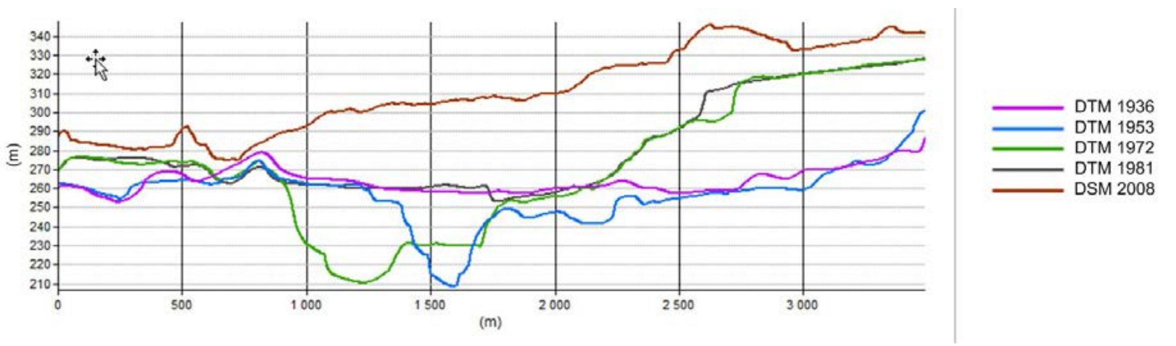

Fig. 16 Analysis of Profile 4