3D modelling of the Danube River
and the floods during March and April of 2006
in Nagymaros and Szob

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I. Introductory data about the autor

Ramiro Marco Figuera, student of Geomatic and Topography Enginnering at the Polytechnic Building School of Barcelona, an institution member of the Polytechnic University of Catalonia.

This thesis is a research made on the scope of the ERASMUS program between the Polytechnic University of Catalonia and the Eötvos Loránd University. It was developed in the Department of Cartography and Geoinformatics, Faculty of Informatics.

The thesis was implemented under the supervision of Associated Prof. José Jesus Reyes Nuñez, in the Department of Cartography and Geoinformatics.

II. Introduction

Every year the Danube (Duna) River uses to flood in the spring. In March and April 2006 the Duna floods up to a really high level in the Nagymaros and Szob villages. The flood goes up to 6 meters from its regular level. Water covered like a half of the villages provoking lots of problems in their inhabitants' normal life.

The main task of this research is the planning and making of a 3D model of the Duna River region called "Dunakanyar" in Hungarian language, including the above mentioned villages, and presenting what happened and how those floods affected the population living there. I also tried to make an analysis of this situation and find some options or alternatives due to the security systems and the emergency service.

The Duna River:

The river originates in the Black Forest in Germany as the much smaller Brigach and Breg rivers, which join at the German town of Donaueschingen and being known as the Duna River from here, flooding southeastward for a distance of more or less 2850 km (1771 miles), passing through four Central and Eastern European capitals, before emptying into the Black Sea via the Danube Delta in Romania and Ukraine.

The river floods through or acts as part of the borders of ten countries: Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Moldova, Ukraine and Romania (Figure 1).

Figure 1 The Danube River

Nagymaros:

Nagymaros is a little town situated in the border of the Danube River just in front of the town of Visegrád. It's connected with this town by ferry. It is situated in the kilometer XXXX. The population in 2001 was 4469 inhabitants and it has an area of 34,39Km^2. In this town there's a hydrographic station from where I took some water flood data.
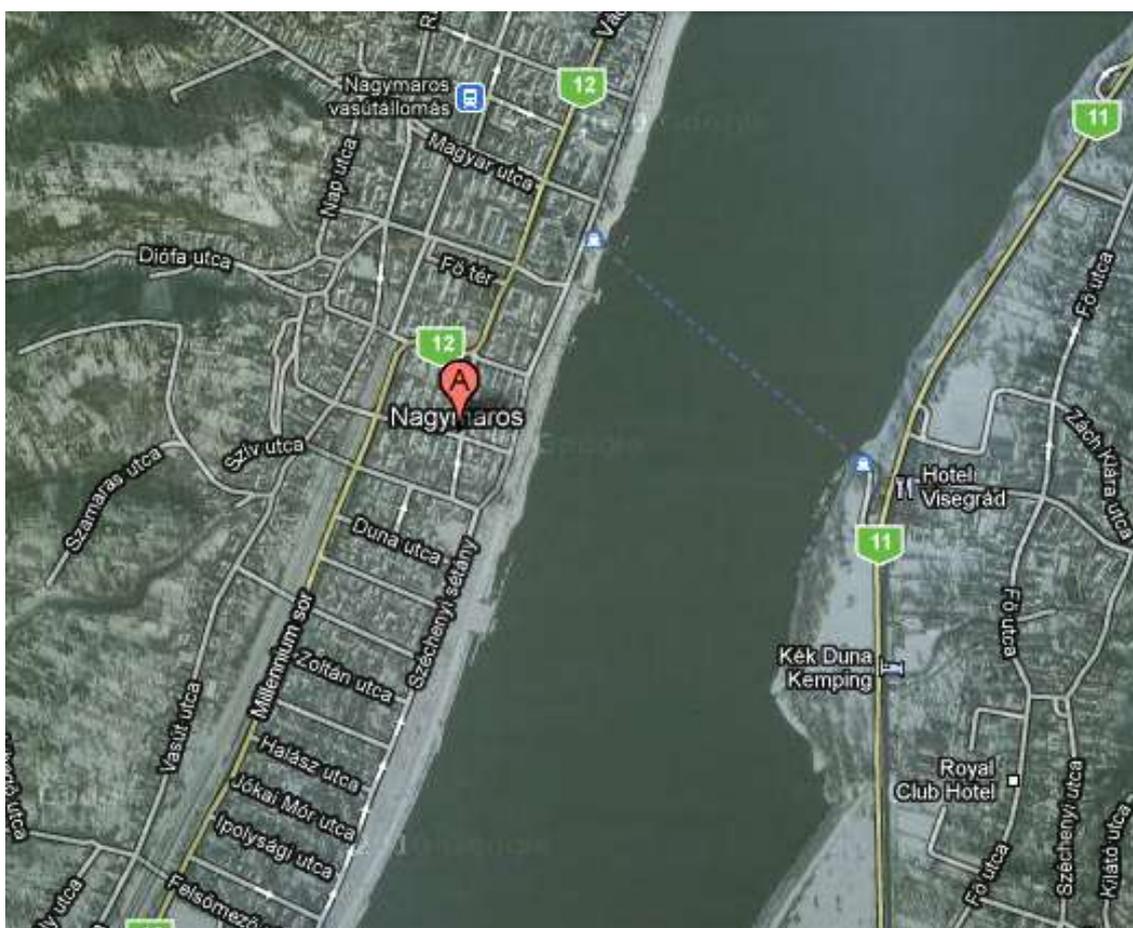
Figure 2 Nagymaros

Szob:

Szob is a little town situated in the border of the Danube River. It's also situated in the boundary between Hungary and Slovakia. The population in 2008 was 2971 habitants and it has an area of 20.07 Km^2. In this town there's a hydrographic station from where I took some water flood data.
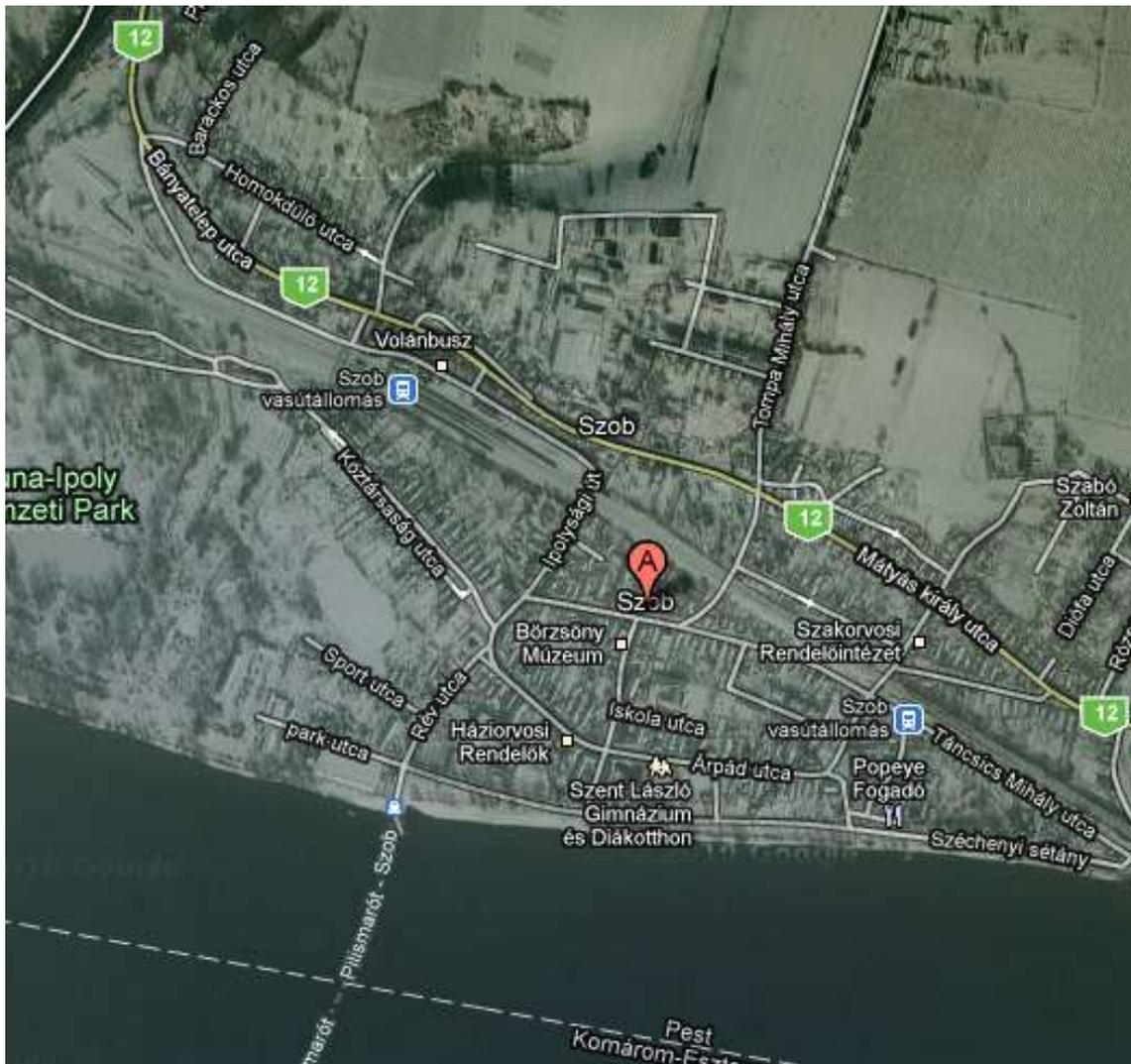
Figure 3 Szob

III. Project workflow

In this project I needed to study the use of some new software as ArcScene from ESRI and Microsoft Access from. I can resume the whole process in 7 main parts:

1. Getting ground data:

It was the easiest part of the project. I obtained the ready information from János Mészáros, PhD student in the Department of Cartography and Geoinformatics. The data was extracted using the software Global Mapper and it belonged to the DTA-50 database (digitized topographic maps at scale 1:10000), made by the Institute of Military Cartography of Hungary. The data was stored in a unique 300Mb file in XYZ format.

2. Processing ground data:

My task during the first part of the process was on the analysis of the XYZ file, to know in detail its' structure and other characteristics .

The first step to work with this data is to change it to a TXT format. Because of the large size of the original file, I had to divide it into 300 files of 1Mb each. Once I had those 300 files I opened them one by one and changed points per comas. This step was needed to avoid any difficulty using the regional configuration of my computer. Once I had this done, I started the more difficult and complex part of the project.

I had to put this data into the ArcGIS software, but before this step I transformed all the files to a DBF format, because ArcGIS doesn't recognise the TXT format, offering the options to import data in XLS or DBF format. I chose DBF format because is the database format used by ArcGIS software.

Next I used Microsoft Access software to change the format from TXT to DBF. Obviously I knew that I could do the same using Excel software, but I preferred to use a more professional (database oriented) software from the same Microsoft product family.

- The process in Microsoft Access was really easy to do, comparing to the process in Excel. I didn't need to open tables one by one to change the format. The process was making a database and importing all the tables to that database. Then I chose the format that I would to save those tables. If you choose DBF format the tables are save to this format automatically.

    I created a new database and imported a table chosen TXT format
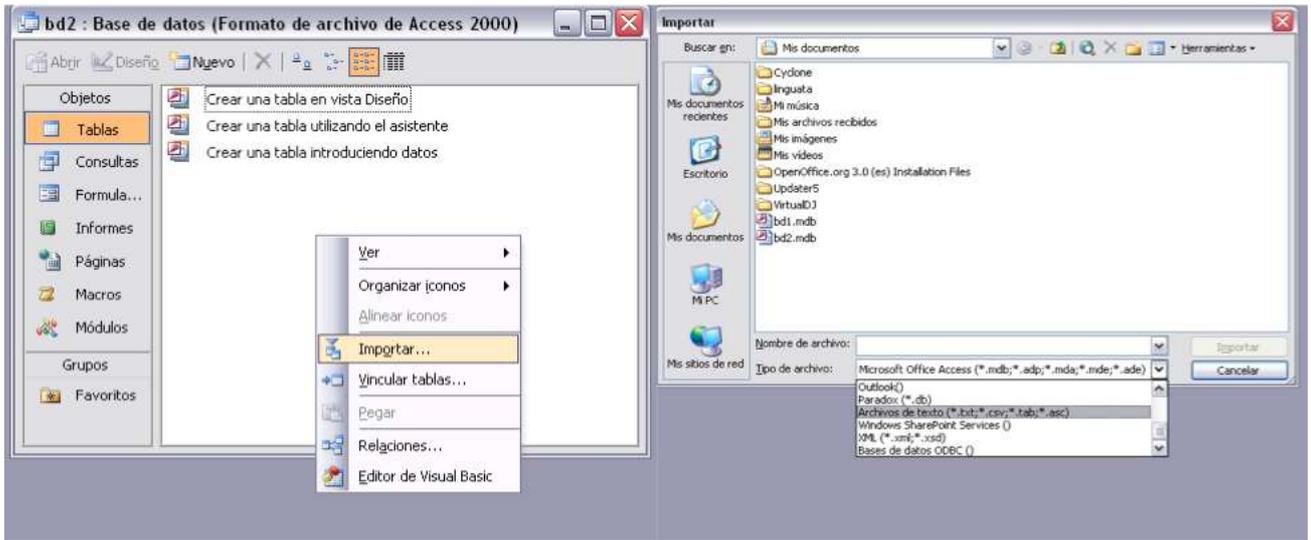
Figure 4 Importing TXT format

- Using the Import assistant I chose Advanced Options and there I chose A LONG format
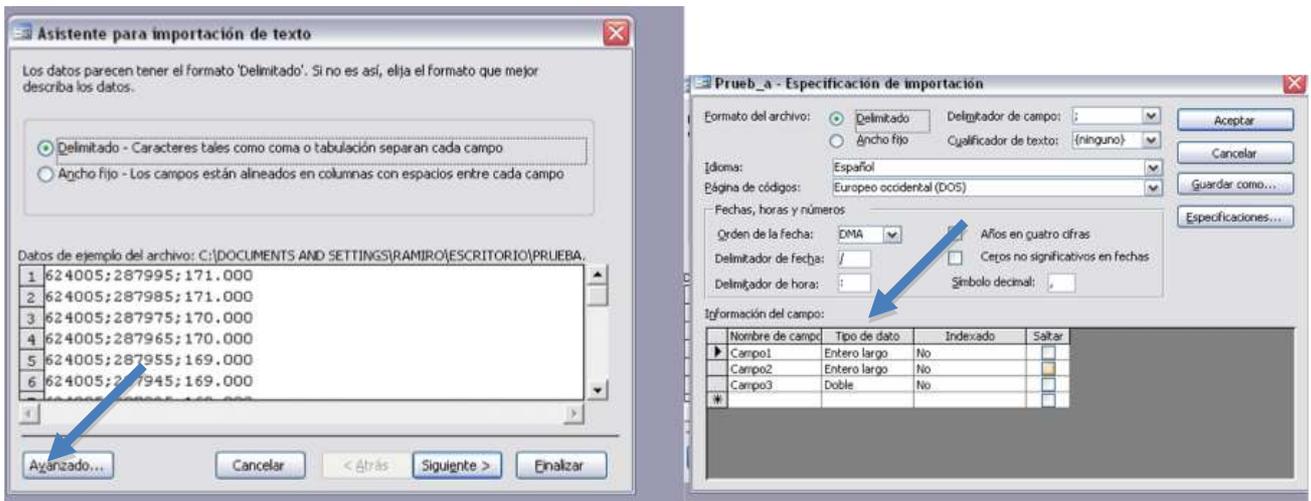
Figure 5 Choosing LONG format

- Then selected Import a new table and I changed the names of the fields to x,y,z. After it I put a main key and wrote the name of the table to save it.
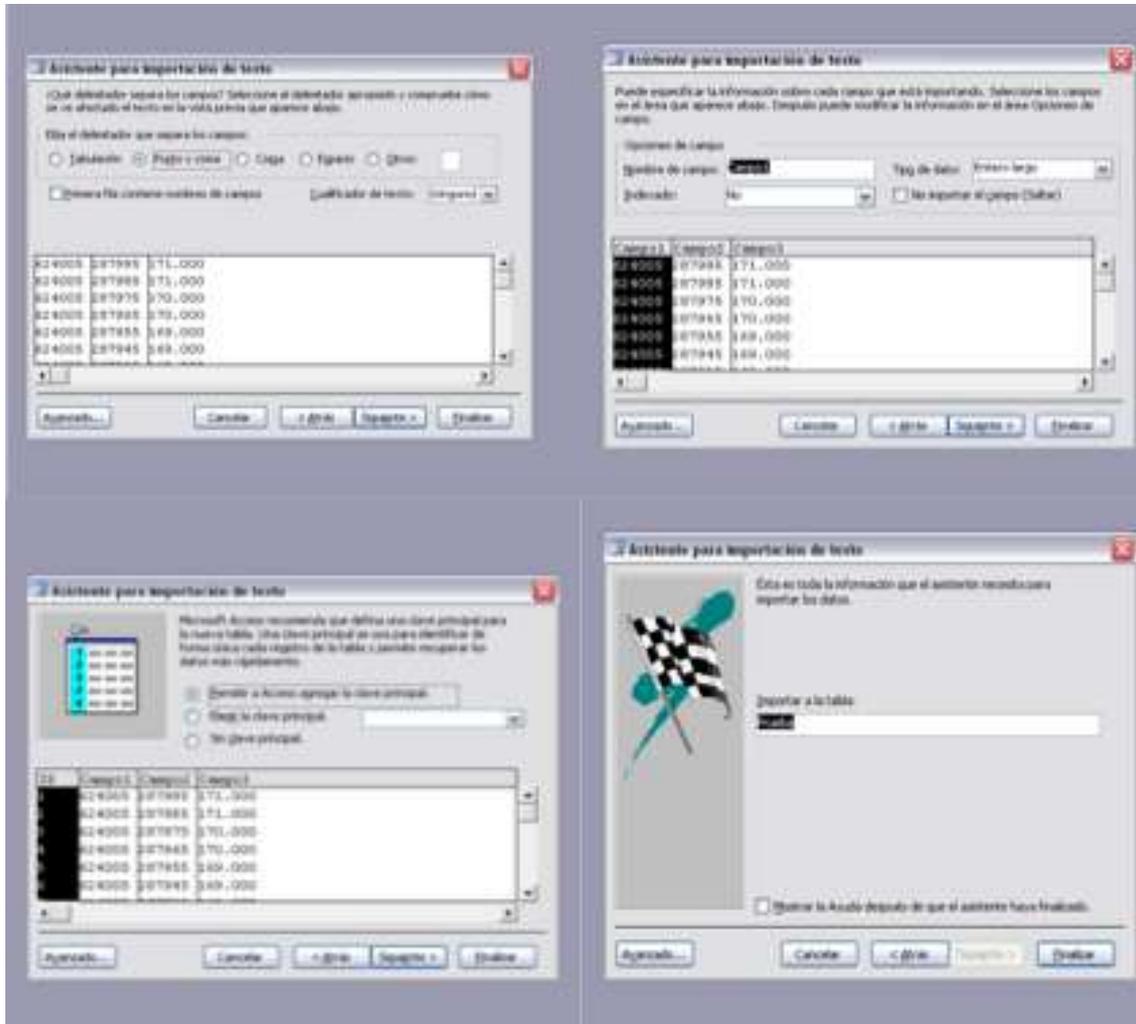
Figure 6 Creating and saving the table

- The final step was to export the table as a DBF (IV) database
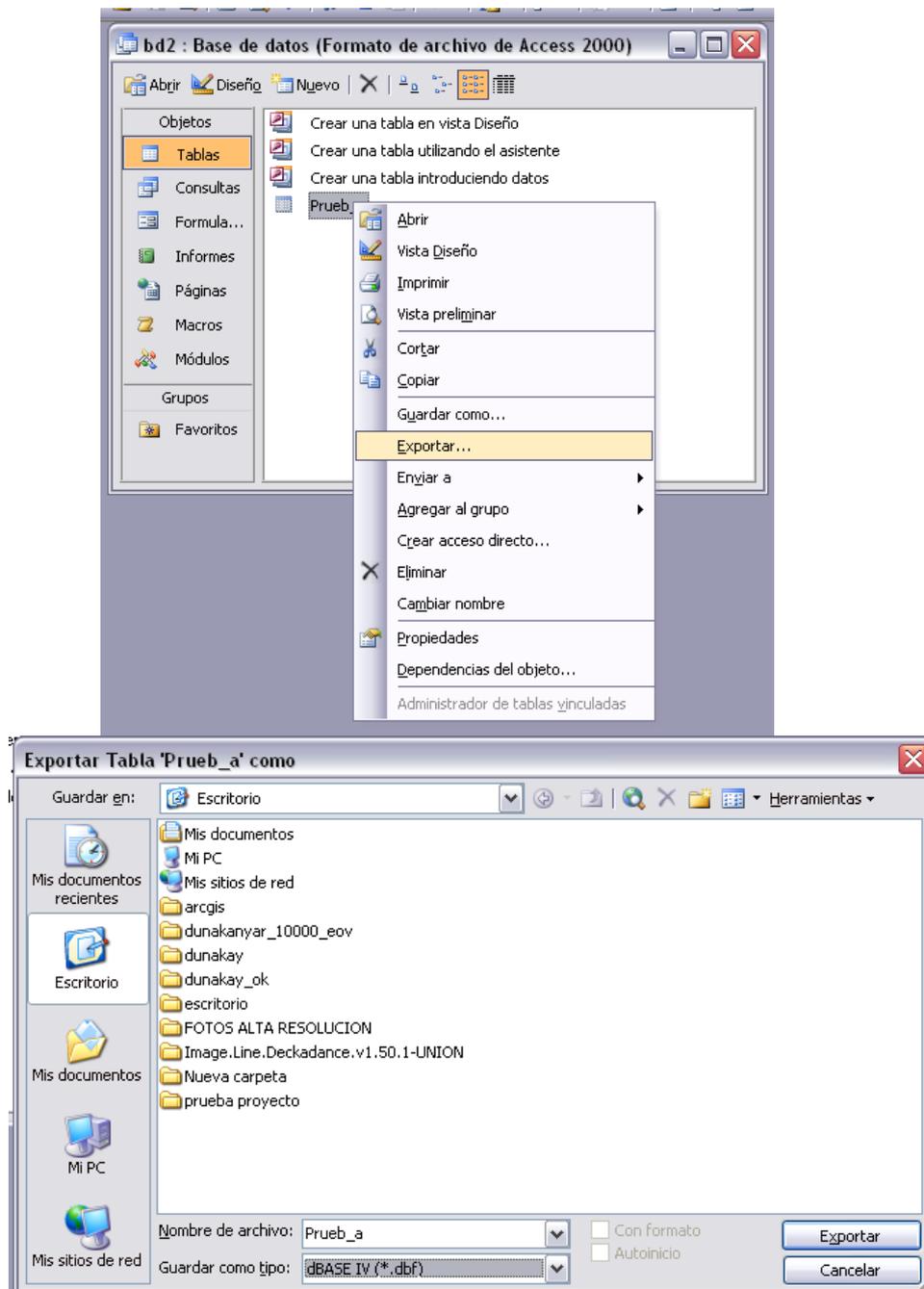
Figure 7 Exporting to DBF (IV)

Before importing all the data to the ArcGIS I had to know which projection is used in Hungarian official maps. The projection used for all the geodetic points, maps and other ground data in Hungary is the EOV (Egységes Országos Vetület, Uniform National Projection). Here I add some information from the projection extracted from the Internet (http://lazarus.elte.hu/gb/geodez/geod2.htm):

Name:
EOV
Egységes Országos Vetületi rendszer
(Uniform National Projection system).
Description:
The EOV is a plane projection system used uniformly for the Hungarian civilian base maps and, in general, for spatial informatics. (Base maps: 1:1000, 1:2000, 1:4000 large scale maps for cadastre and 1:10.000, 1:25.000, 1:100.000 topographic maps.)
Geometric classification:
Conformal cylindrical projection in transversal position.
Date of introduction:
1972-1975
Parameters:
Reference surface:
The IUGG GRS 1967 reference ellipsoid (Geodetic Reference System of International Union of Geodesy and Geophysics, 1967):
a = 6 378 160.000 m
b = 6 356 774.516 m
Ellipsoidal geographic coordinates: ,
Projecting sphere:
A Gauss-sphere fitted to reference ellipsoid at the normal parallel.
It is used for Gauss-sphere:
its radius: R = 6 379 743.001 m
and its spherical geographic coordinates: ,
Normal parallel:
Defined as average of latitudes for Hungary, with ellipsoidal and spherical latitudes below
 = 47°10'00.0000"
 = 47°07'20.0578"
Origin of geographic coordinates:
The Equator and the Greenwich meridian
Origin of projection:
A point on the meridian of site "Gellért-hegy":
 = 47°06'00"
 = 0°0'0"
the plane coordinates as
x_o = 0.0 m
y_o = 0.0 m
and by computing the ellipsoidal geographic coordinates:
 = 47°08'39.8174"
 = 19°02'54.8584"

Origin of EOV plane coordinates:

Origin of the EOV plane coordinates is moved to South-West with respect to origin of projection such that all possible EOV coordinates be positive for Hungary:

$X_{EOV} = x + 200\ 000.000$ m

$Y_{EOV} = y + 650\ 000.000$ m

Projection zones:
A single cylindrical zone covers the area of Hungary in East-West direction.

Scale factor: $m_o = 0.99993$

Linear distortion:

Along the *y* axis:	-7 cm/km
North of Hungary:	+26 cm/km
South of Hungary:	+23 cm/km

Area distortion:

Along the *y* axis:	$-1.4\ \text{m}^2$/ha
North of Hungary:	$+4.5\ \text{m}^2$/ha
South of Hungary:	$+4.5\ \text{m}^2$/ha

Then I imported all the data into ArcGIS software, this time one by one using the XY data. In this step I also chose the reference system to work. Choosing the Hungarian EOV system was really easy, because it is included in the ArcGIS software. I repeated this process with each table.

- The first step is to import the XY data and choose the table that we want to import.
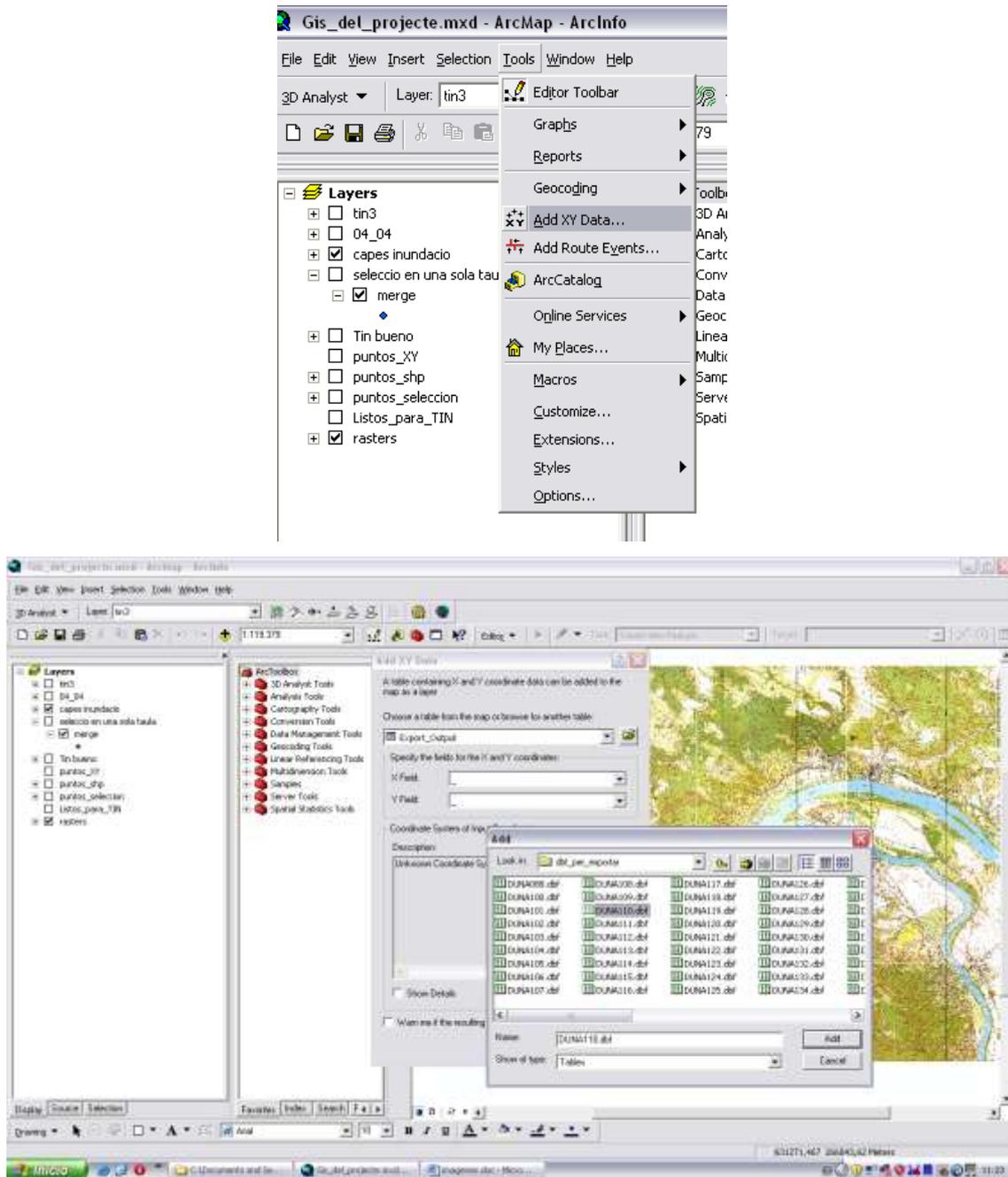
Figure 8 Importing XY data

- Then I chose the fields where the X and Y data is stored. I had to choose the reference system too. In this case I found it in the projected coordinated system and in the national grids. Its name in ArcGIS is "HD 1972 Egyseges Orszagos Vetulet.prj"

Figure 9 Choosing the reference system

- Finally we have represented the XY data in the software.
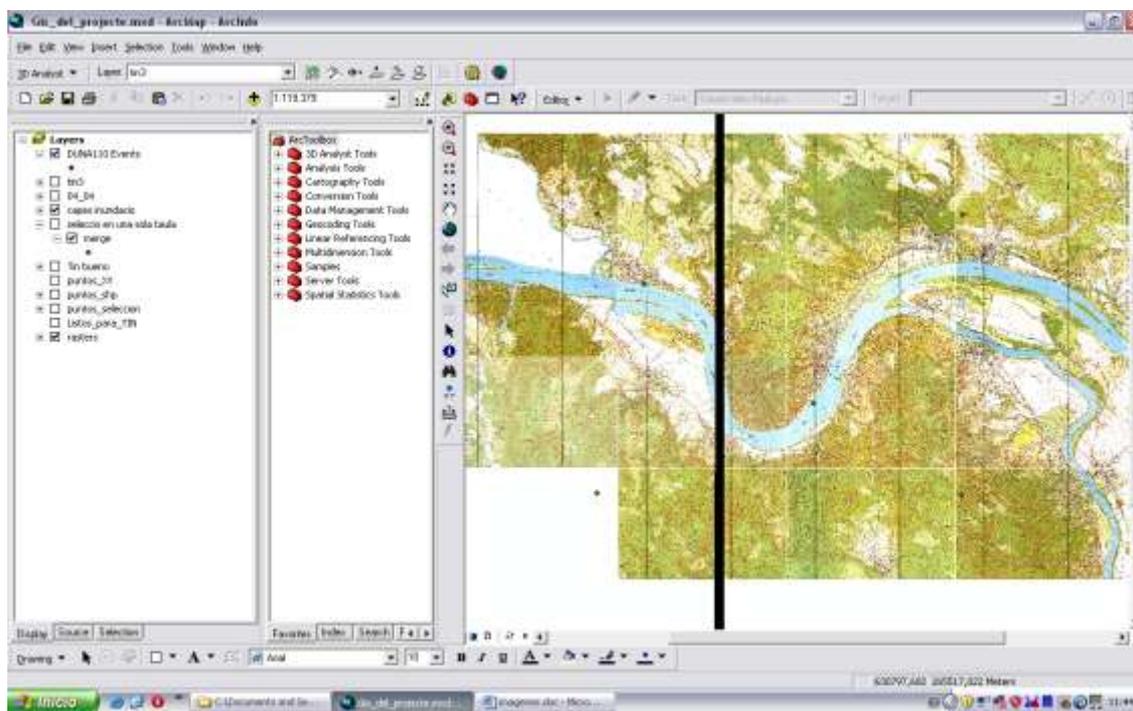
Figure 10 Final result of one table

Once I had this data in the software, the next step was to delete all the data that I don't need. I did that because from the beginnings I was working with ground date of all the country and I only needed a small part of it.

To know what part of the whole data I need, I put 21 georeferenced map sheets into the software. With these maps and the ground data in the software, the next step was to select the points placed within the map sheets.
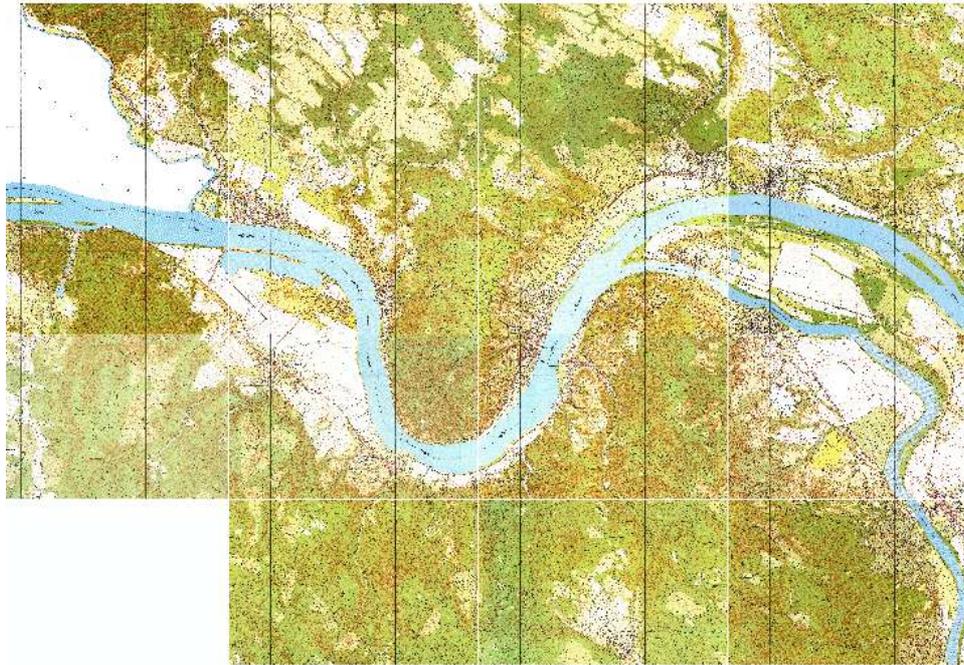
Figure 11 Map sheets

Next I saved all those ground data points into a unique DBF table. I did it first selecting those points, and later going to the Data Management Tools, to choose the Merge Action. I introduced one by one all the tables following the same process, and the final result was only one table.
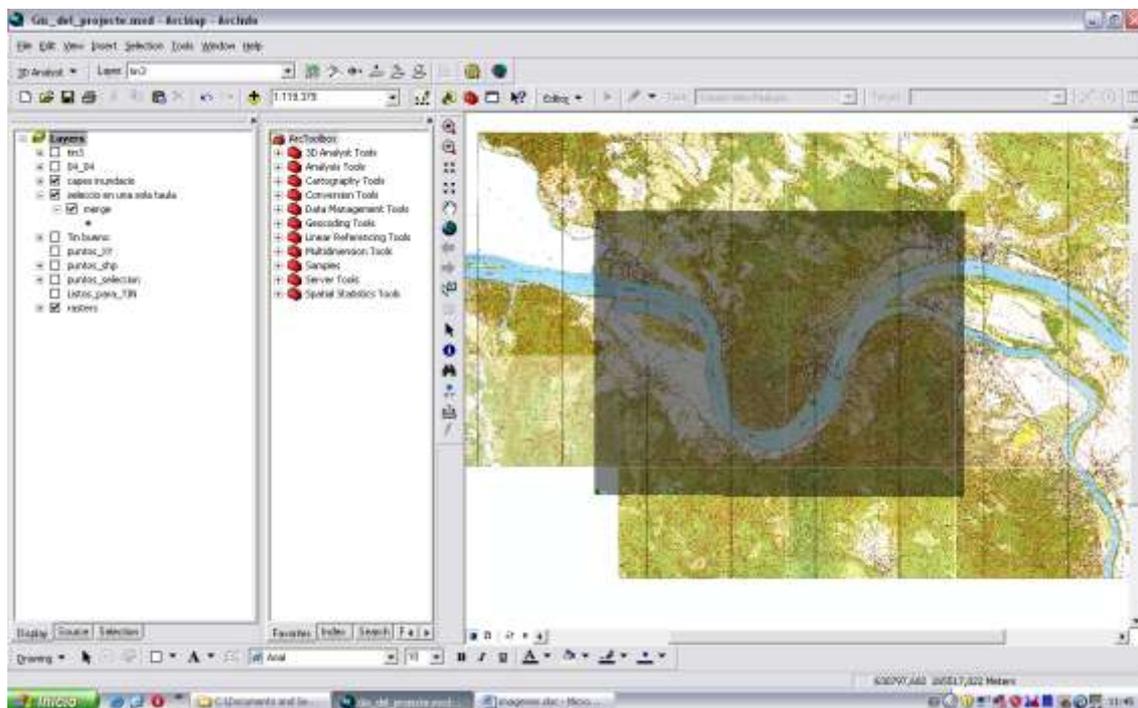
Figure 12 Merge table result

This step was necessary because working with one table is always more practical, easier and faster than working with 91 tables as I was working. Finishing this part of the process the data was ready for the next, more complex step.

3. How to create the 3D model

The first question to answer is how I do that?, that is what software and technology can be the more appropriated to make my 3D model. To answer this question I was doing some groundwork through Internet, visiting some geoforums. I found two possible solutions:

a. The first one and directly discarded was working with AutoCad Civil software. I discarded it because going on that way includes changing totally my work mentality, using non-cartographic software and being the hardest way to reach my objective.

b. The second, chosen way was working first with 3D Analyst in ArcGIS and after it exporting all this information to the ArcScene software.

To make the 3D model I followed the next steps:

- Using the 3D Analyst extension → Create/Modify TIN → Create TIN from features (Figure 13)
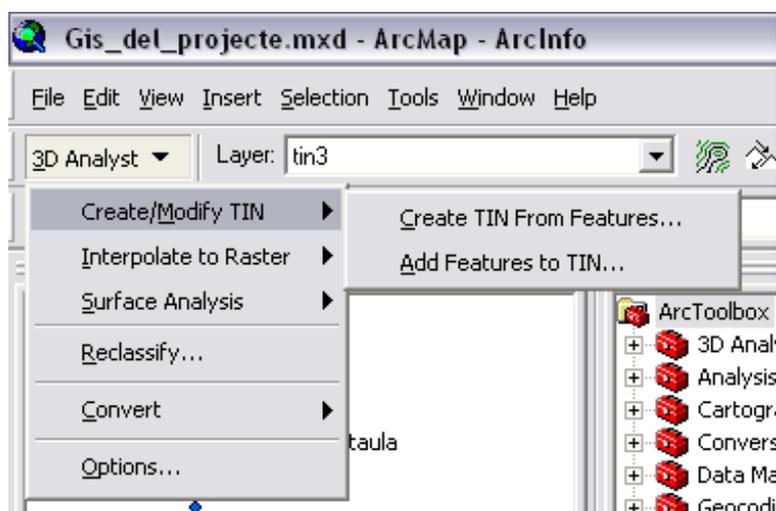
Figure 13 Creating TIN

- Choose the layer → Height source : Z → Triangulate as: mass point → Tag value field: none → Choose the output route:
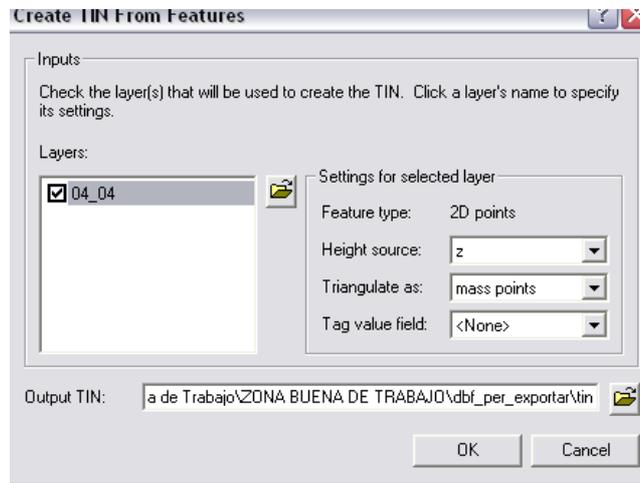
Figure 14 Saving TIN

- Finally, the resulting TIN model is displayed
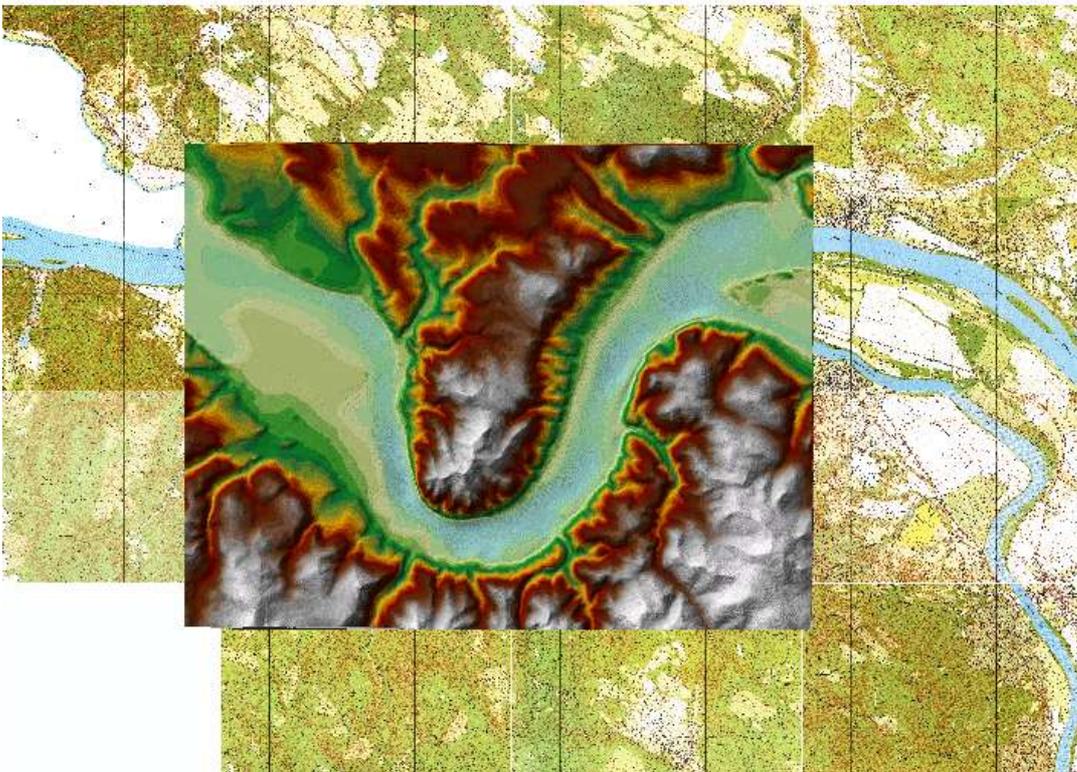
Figure 15 Final TIN

4. Processing the ground 3D model

To manage the 3D model was used the ArcScene software developed by ESRI. With this software we can manage the TIN format and see it in XYZ axes. This software is really easy to use. I can resume the process in the next steps:

The first step is adding data to the Scene layers as we used to do in ArcGIS. I obtained a 3D model in only one colour.
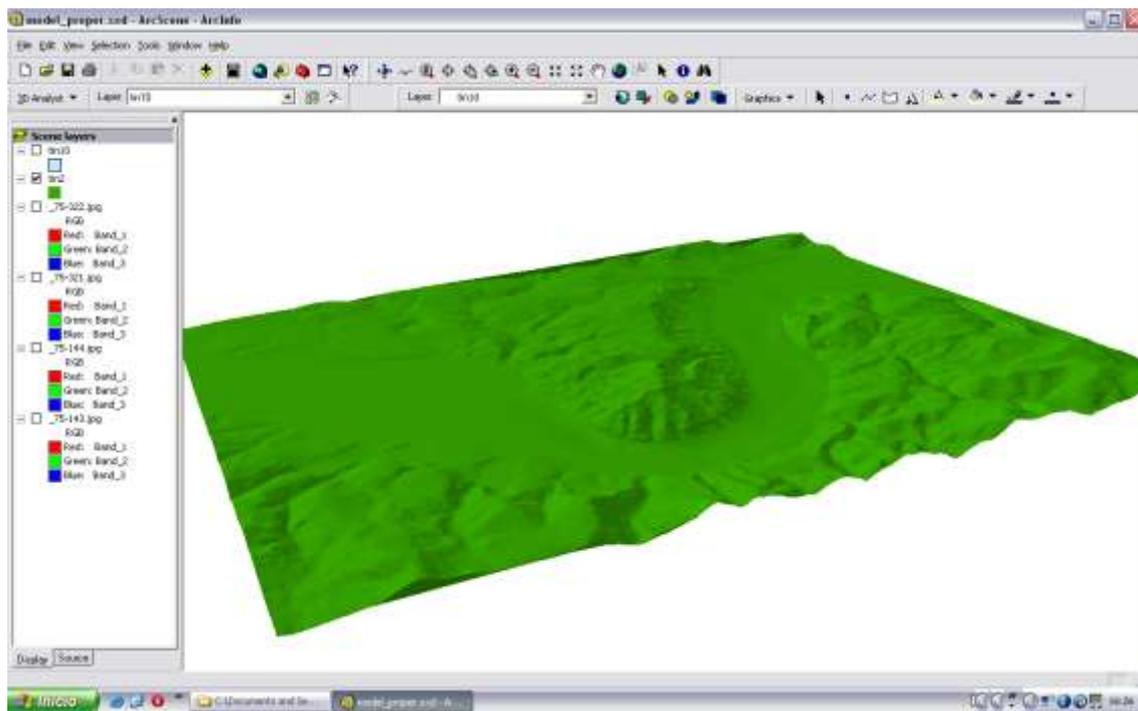
Figure 16 TIN displayed in ArcScene

The next step was to introduce some georeferenced maps sheets into the model. These map sheets obtained the height information from the TIN to model them. The process is resumed in the next steps:

- I added one by one the four map sheets before adding data
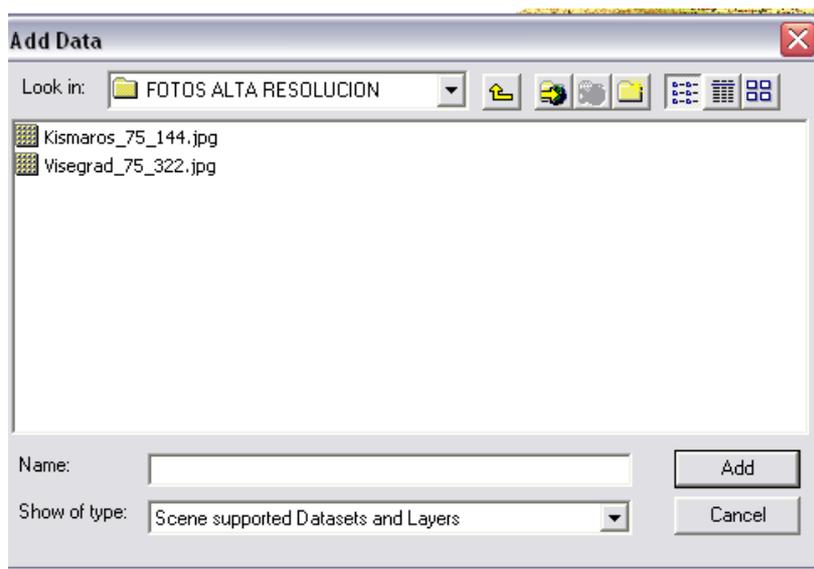
Figure 17 Adding map sheets

- I clicked on the Layer command and then on Properties. After it I clicked on the Base Heights flap and selected "Obtain heights for layers from heights". Then we had to choose where our TIN was stored. On the Z UNIT section I chose Custom and a conversion factor of 1,000.
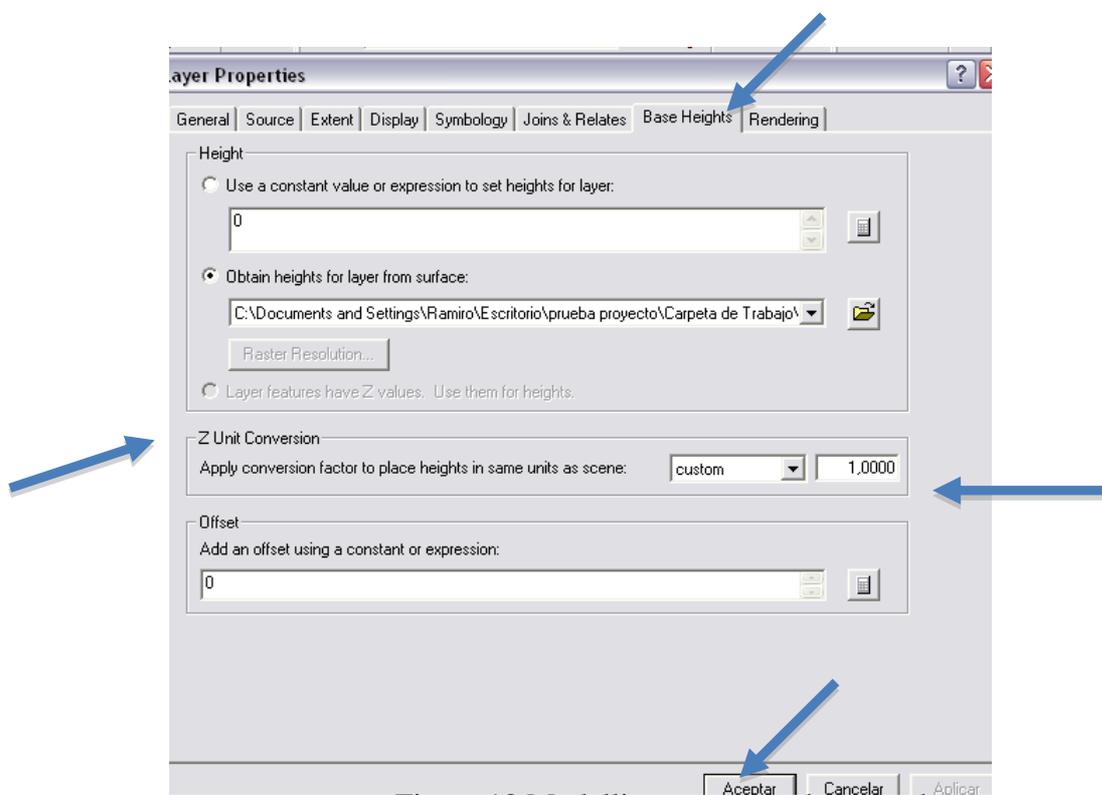
Figure 18 Modelling   the map sheets

- Then I pressed Acept and the modeled map sheet was made.
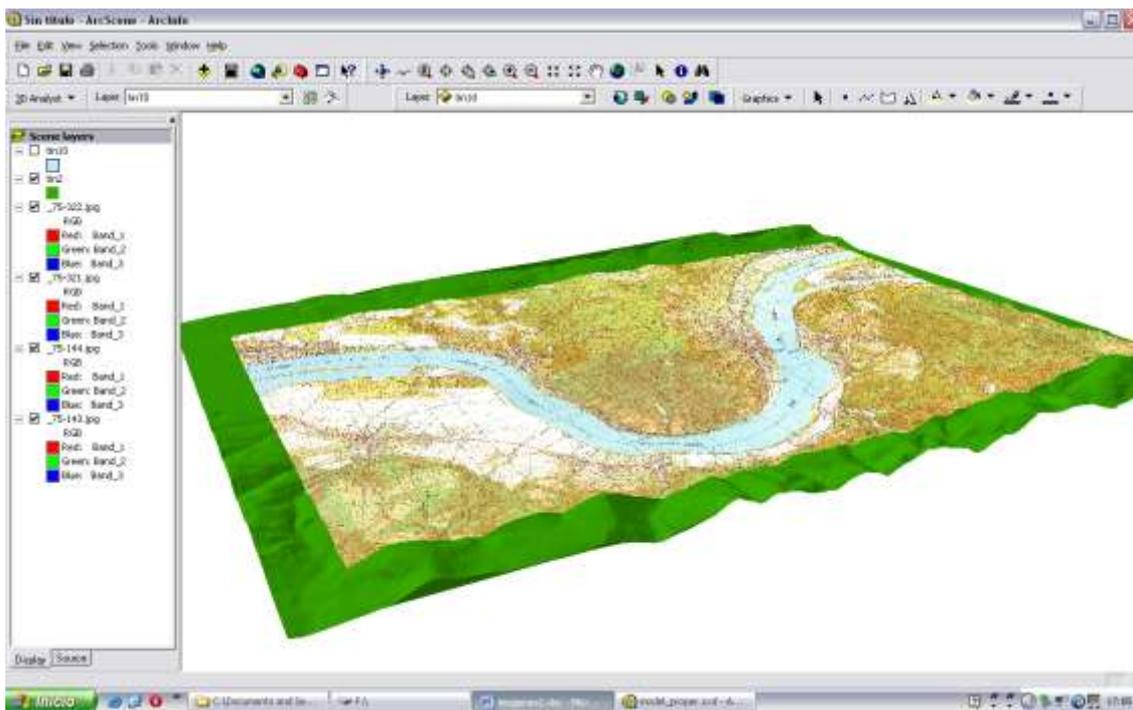
Figure 19 Obtaining the modelled map sheets

- The final step is unselecting the TIN having the final map sheets modelled.
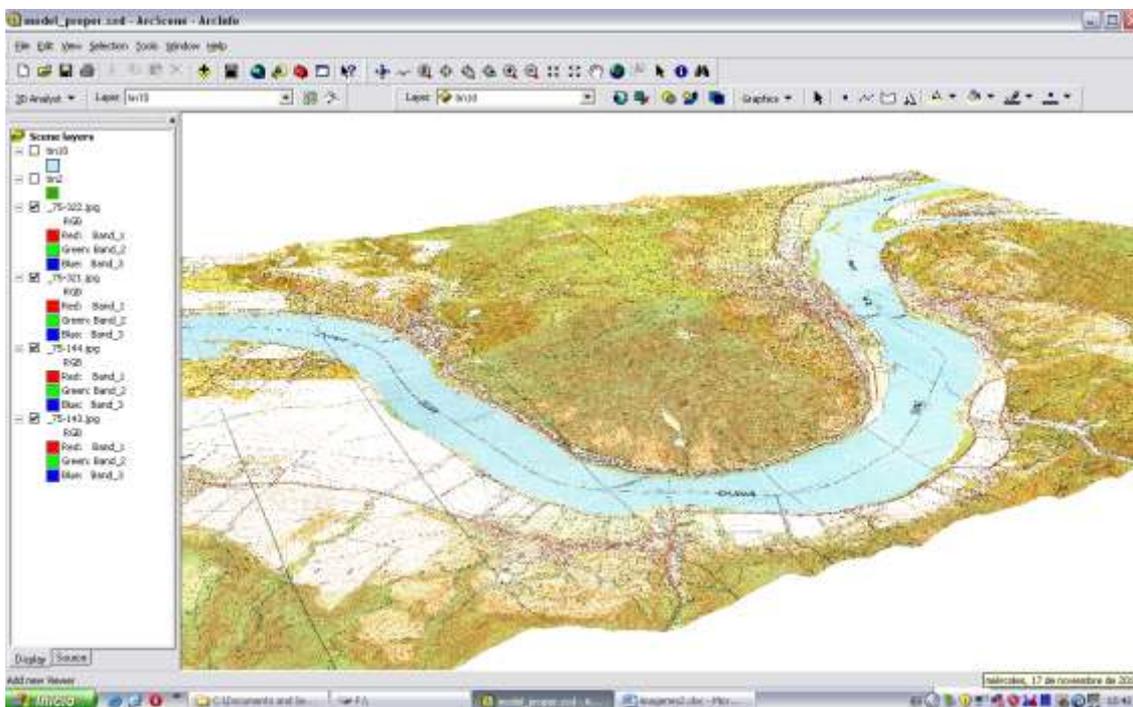
Figure 20 Final modelled map sheets

5. Getting water data

To get the water information my professor, Jesus Reyes told that there's a web site (www.vizadat.hu), which collects all the water height data. This web site is written in Hungarian language and I needed some help to translate and navigate through the site.

- Once in the site, we should go to Felszíni vízállás idősorok (Time series of surface water) section.

Figure 21 Main page from www.vizadat.hu

- In this section I chose the hydrographical station situated in Nagymaros and gave the lapse of time of the data.

Figure 22 Choosing the options

- Then clicking on Eredmények listázása we get the information in graphic and table format
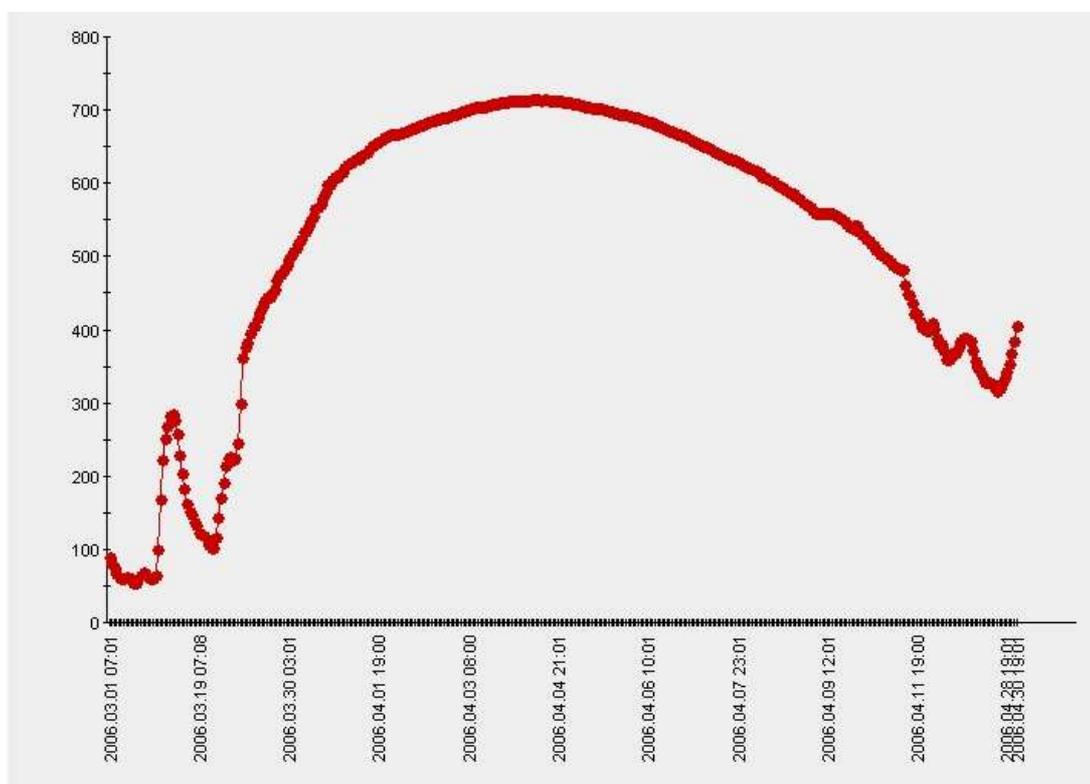
Ssz	Időpont	Vízállás
1.	2006.03.01 07:01	90
2.	2006.03.01 19:01	82
3.	2006.03.02 07:01	74
4.	2006.03.02 19:01	67
5.	2006.03.03 07:01	62
6.	2006.03.03 19:01	61
7.	2006.03.04 07:01	61
8.	2006.03.04 19:01	62
9.	2006.03.05 07:01	60
10.	2006.03.05 19:01	60
11.	2006.03.06 07:00	55
12.	2006.03.06 19:00	55
13.	2006.03.07 07:00	60
14.	2006.03.07 19:01	65
15.	2006.03.08 07:01	59
16.	2006.03.08 19:01	67
17.	2006.03.09 07:10	63
18.	2006.03.09 19:01	61
19.	2006.03.10 07:01	60
20.	2006.03.10 19:01	64

Figure 23 Data presentation in graphic and table format

6. Processing the water data

Similar to the ground data, I needed to process the water data before using it. The selected data was measured between 25th March and 26th April 2006. The first step was putting the data into an Excel sheet to make some calculus. In a normal day 3 or 4 measurements were made, but in the days with big floods their number was increased to 20 measurements. Because of this, the first step was to make some average calculus to have one average measurement per day. I made it for the Nagymaros station and for the Szob station, having all the data in centimetres.

Figure 24 Data calculus

In figure 24 in red colour can be seen the average calculus per day. I used the average data to create the water floods shapes.

The next step was to decide how to put this data to the GIS software and how to make the 3D shapes. Before realizing this step I found some problems to solve. The first one was to decide which points I can use to make the TIN shape. After doing some attempts finally I decided first to make one table per day containing the data from the hydrographical station, and second to complete the shape, including the XYZ coordinates from the points, which were in the four corners of the map sheet of the zones of Nagymaros and Szob. Once finished this task, I saved all those tables in XLS format.

x	y	z
636913	274578	111,27
642926	270311	110,39
648215	267045	110,39
648225	277085	110,39
635255	277115	111,27
635255	267095	111,27

The new XLS table was imported in to the GIS software, following the same steps described in the ground data section. I used the "Import XY data" and then I created the TIN shapes. I did the same for each table because I needed one TIN shape per day, obtaining a total of 30 shapes.
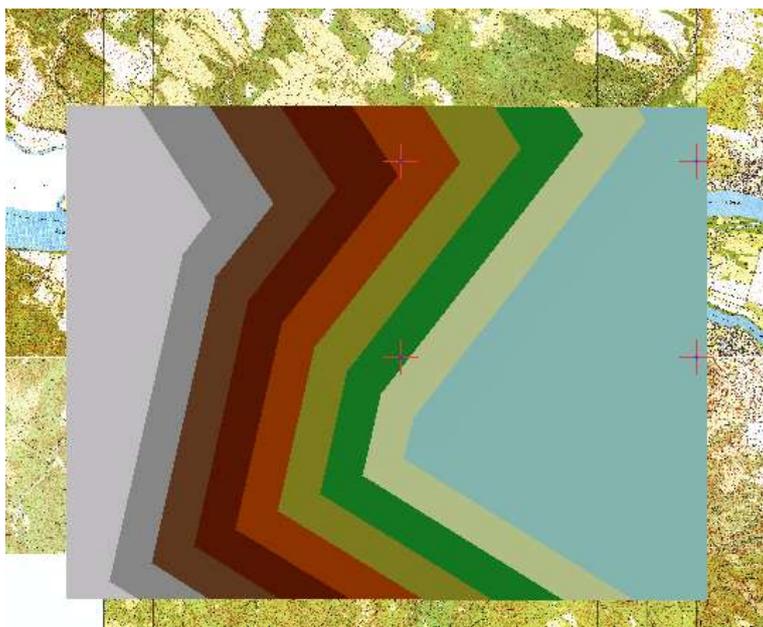
Figure 25 Water TIN shape

7. Processing the water 3D model

The process of water data was the same than with the ground data. I imported the TIN model into the ArcScene software and then I chose a colour for the shape. Selecting and running in an animation the different TIN shapes we can have an idea about the magnitude of the floods and what areas of the zone where more affected.
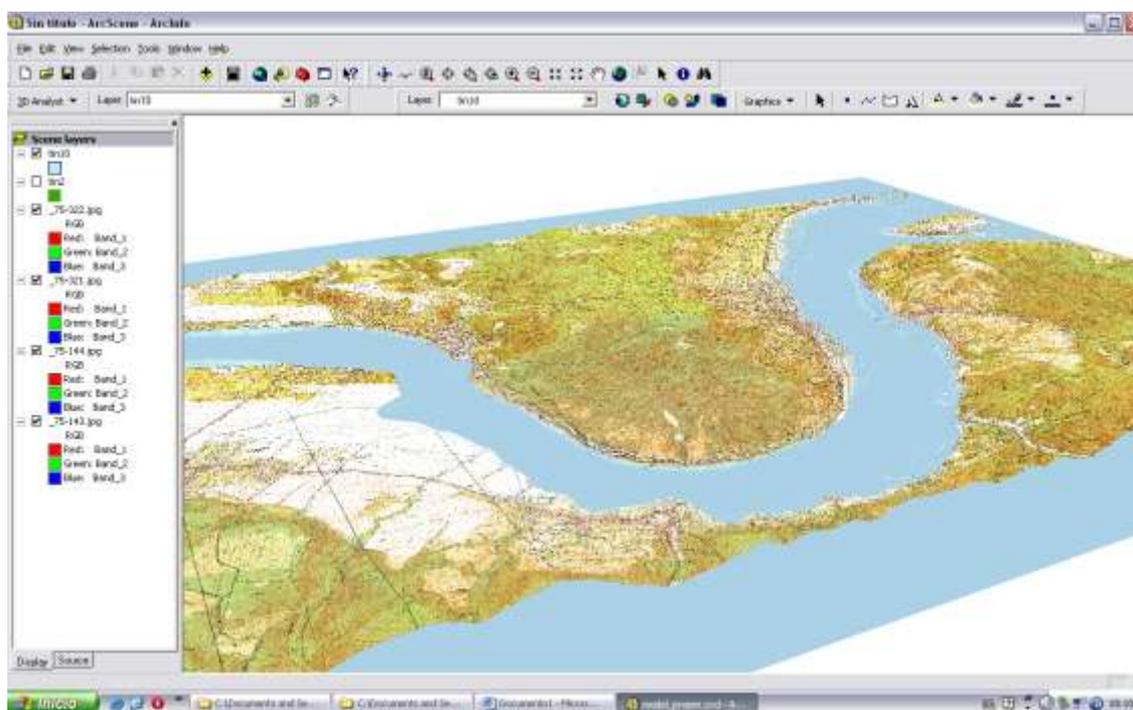
Figure 26 Final result

IV. Conclusions

The final results of this research are two 3D models, one based only on ground data and 30 shapes made using water data to present the Danube flood in this region in March, April and May 2006. Combining it, on those zones of study can be obtained a total of thirty 3D models of the floods. Those models can be used to make some studies about how the water floods affect those towns and their habitants. It also can be used to make some studies about what the Hungarian government could do to fix this annual situation or to, at least, reduce the impact on the population in these towns. In my opinion I can say that the floods in this part of the country are very regular and due to the proximity of those towns to the Duna River it's very difficult to fix it.

V. Working with high-resolution map sheets

In interest of obtaining a more rigorous result, I asked my tutor if I could work with high-resolution map sheets. I obtained two high-resolution Nagymaros map sheets from János Mészáros to begin this work. The reason of this request was that using the actual scanned map sheets when you zoomed in the resolution was really low, presenting a very pixeled image on the display.

I considered that if somebody wants to make a study about the impact of the floods in the Nagymaros zone, high-resolution map sheets should be used to see really as far as the water level can cover the riversides within the town.

The first step was importing both images to the ArcGIS software and georeference the sheets.

- With the maps in the software I selected the Georeferencing module.

Figure 27 Georeferencing module

- Then I deactivate the Auto adjust mode and I began to georeference the map. If we know the coordinates of the square we can click on the map, adding a control point and typing the coordinates into the equivalence table. Other possible solution is that we can click into the square of the map adding a control point and go to the low-resolution map sheets, which have the same scale, and click on the same square. I chose the second one, because it was faster than the first one.
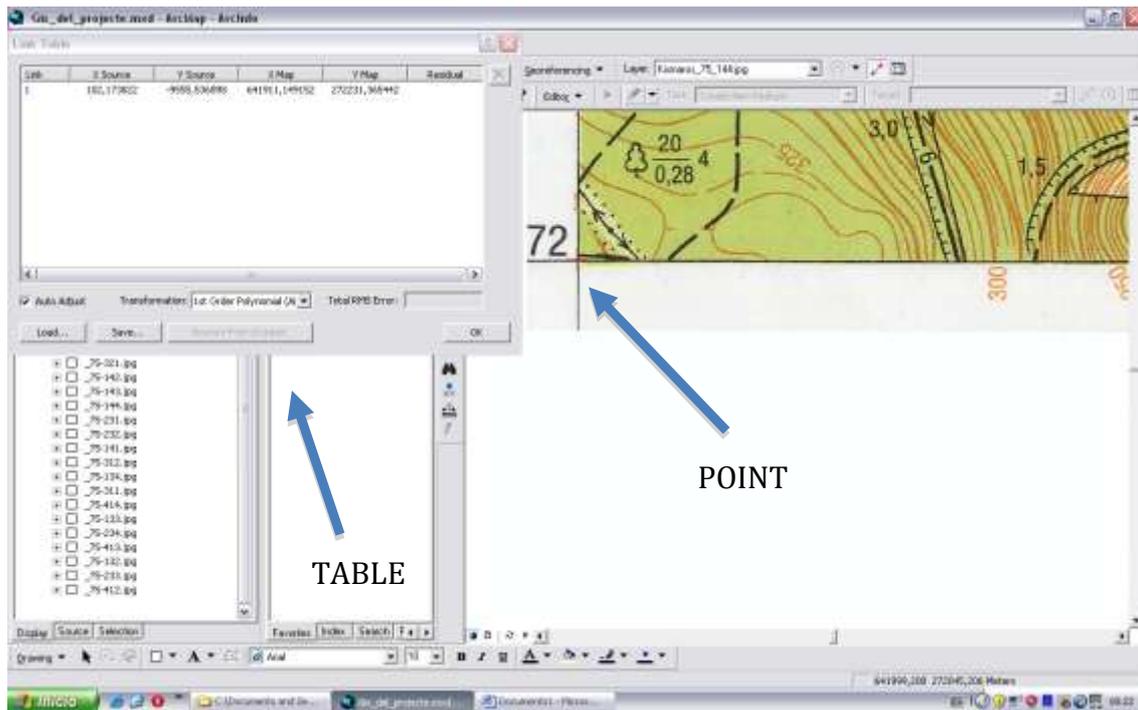
Figure 28 Georeferencing

- Once we have this map sheet referenced we go to the Georeferencing module and choose Rectify. We should save it in JPG format.
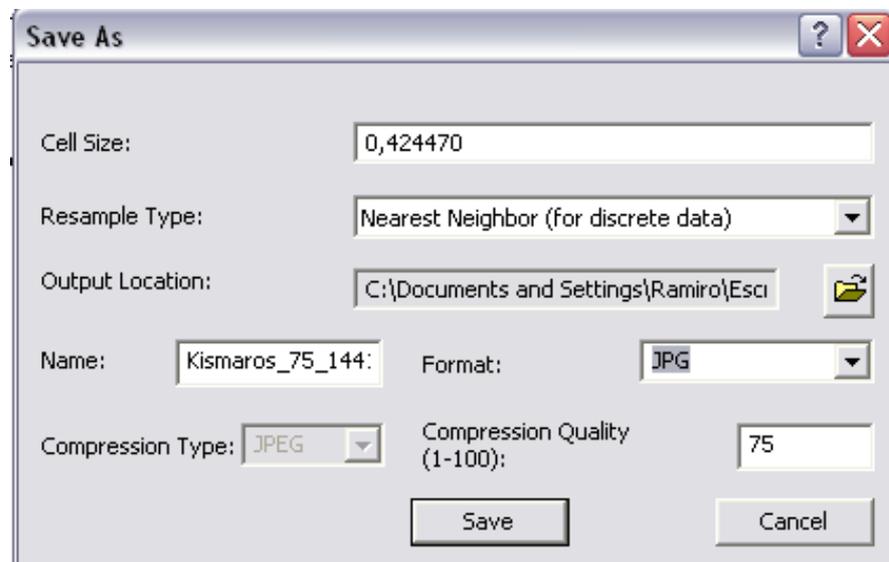
Figure 29 Saving the output image

The next step was to import those map sheets into the ArcScene. The process was similar to the followed steps working with the TIN: clicking Add Data and selecting the maps sheets, and. repeating the process to model the map sheets to the TIN as we did before.

After finishing this process, I hoped to zoom in the Nagymaros zone and to have a more real and detailed vision of the magnitude of the problem. That was that I expected, but the real result was pixels again (figure 29).
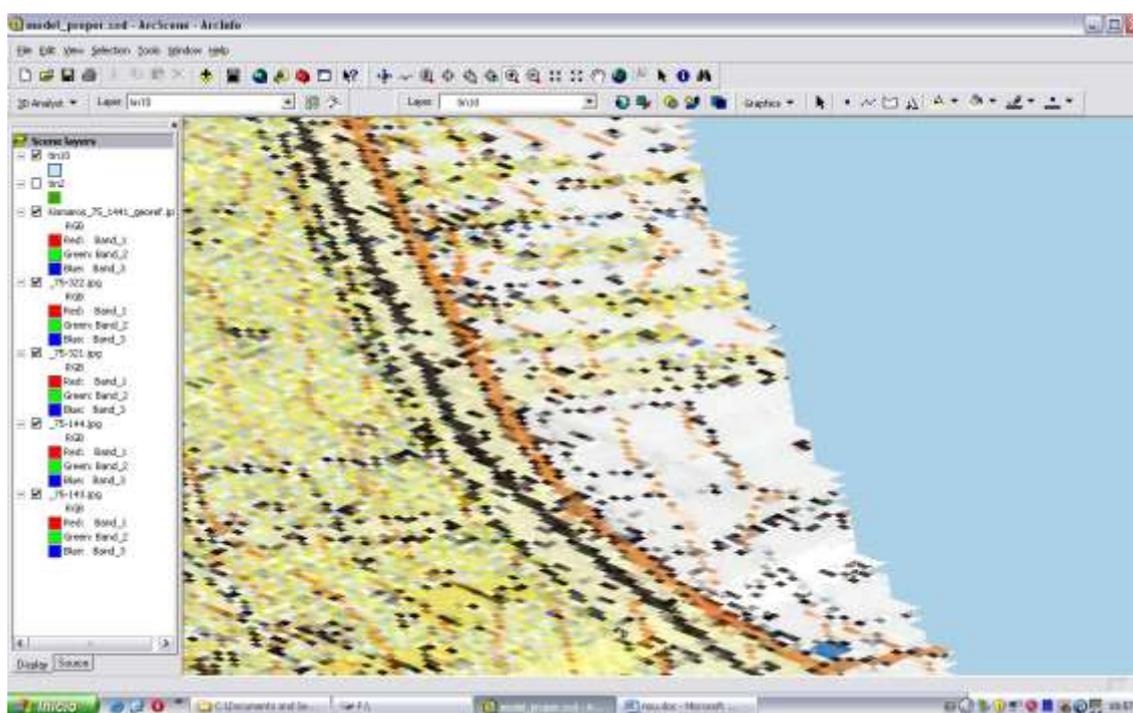
Figure 29 Pixels in the high-resolution images

I have two theories about the negative result obtained with the high-resolution images:

- One of the reasons could be the image pyramid process, because probably the software is working with the less resolution shape of the image.
- The software can't handle those high-resolution images. Probably this software was created to work with 3D data but not with shapes with high-resolution images.

VI. Alternative workflow, working with remote sensing methods

From the first time I was thinking about to use some remote sensing methods because this is my speciality on the Geomatics engineering degree. Working on that way is faster and easier. The only negative point is that the satellite images are very expensive and the result depends on the quality of the images.

In this case I recommend working with multispectral images with three bands or radar images.

- If we work with multispectral images we have at least three bands (blue, red and green bands). Then we can see this image in a false colour construction combining the bands. Those images use to have a very high resolution, depending on the satellite used to take the images. If we work with the Thematic Mapper Sensor carried on the Landsat 5 satellite we will have a resolution of 30m. Otherwise working with the Geo-Eye 1 we will have a resolution of 1.65m working with the multispectral sensor. The negative aspect is that always the result depends on the weather conditions because if when the picture is taken the sky is cloudy, then we can't work with this image.

- Using radar images we have only one panchromatic (B&W) band. With the SAR antenna carried on the TerraSar-X satellite we can obtain a 1m resolution, working with the SpotLight mode. The SpotLight mode can only work with a 10km x 10 km image. The positive aspect of working with radar images is that we don't depend of the weather conditions or if it's night or day. This kind of satellites can work always.

I tried to work with some images from the Landsat 5 satellite, but on March an April of 2006 the cloud cover in the image was circa 75-80%, being totally impossible to work with it. I chose the Landsat 5 satellite because we can obtain free images from the United States Geological Survey (USGS) web site. The other satellites are always really expensive.

The main aim of the use of the images is not to obtain a 3D model, but to finish faster the study about how the floods affect the zone.

The workflow is very easy. I can resume the process with 3-band images in this flow diagram: First we should analyze the bit level of an image. It usually goes from 0 to 265. Analyzing the bit levels for the water areas we can make a bounding for those levels and assign it for the water areas.

Second, we assign the value 1 to the bits for the water and the value 0 for the rest. We repeat the same process for the image with normal water level and for the image with a high water level.

After the first two steps we have two images with two bit levels. Then we superimpose the images and make some easy bit calculus, writing a little algorithm in Query language to make a comparison: if the bit value from the X_n pixel from the image A is the same that the bit value from the Y_n pixel from the image B, then paint those pixel in red colour. Then if the bit value from the X_n pixel from the image A is not the same that the bit value from the Y_n pixel from the image B, then paint it in blue.

The blue painted area is the area of the flood. If we selected this area and save it as a shape, we can superimpose it in a high-resolution image to see how the floods affected those towns.

As we can see, the process is shorter and easier. To make an study about floods – only about the floods! – it is better to use remote sensing, but if we want to do a 3D model the only method to follow is to work with the initial process developed in this thesis.

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