# BOUNDARIES, FIELD WORK AND GIS MANAGEMENT

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## ABSTRACT

The generalized use of digital maps and Geographic Information Systems has highlighted the need to know the precise boundary lines between the various Catalan municipalities. The Catalan municipal boundaries were defined between 1910 and 1930.

The Institut Cartogràfic de Catalunya (ICC) is working on the Catalan Municipal Boundary Project, the aim of which is to certificate the precise boundaries. The first step of this project is to find out where the landmarks and the boundary lines described in the old legal documents are.

In order to implement this global project, today the ICC involves several branches in the field of cartography: Geographic Information Systems, GPS receivers, differential corrections (by radio, by satellite, net solutions), pen-tablets, PDAs, digital maps, etc.

## 1. INTRODUCTION

The generalized use of digital maps and Geographic Information Systems has highlighted the need to know the precise boundary lines between the various Catalan municipalities.

The Institut Cartogràfic de Catalunya (ICC) is working on the Catalan Municipal Boundary Project, the aim of which is to certificate the precise boundaries.

The Catalan municipal boundaries were defined between 1910 and 1930. It was during this period that the legal documents describing the boundary lines were drawn up. We call these documents “actas”. Boundary traverse surveys were also observed and municipal maps were made reflecting these boundary lines.

With time, such boundary lines have lost precision, as data was transcribed from an old map to a new one. Nowadays few of the old landmarks are still in place. The discrepancy between different boundary lines on different maps measure up to one hundred meters. This issue causes serious problems for territorial administration and management.

In this context, the Catalonian Autonomous Government has started the Municipal Catalan Map Project. The first step of this project is to find out where the landmarks and the boundary lines described in the old legal documents are. This means certifying each boundary line.

## 2. THE HISTORICAL BACKGROUND

It was in the 19th century that the Spanish liberal government became interested in defining municipal boundaries as a first step in creating a just and accurate land registry. But due to the huge cost of this project and also to the difficult political moment, the project was not started until the beginning of the 20th century.

The decree of 23 December 1870 gave the municipalities just two month to delimit and mark off with landmarks their municipal territories. As no external help was foreseen, they had to do everything on their own. Only a few of them did so because of the shortness of time and the especially difficult political situation.

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The law concerning the Spanish land registry ("Ley del Catastro Parcelario de España") dated 23 March 1906, tried once again to delimit and physically mark off the municipal boundaries. This time the law ordered the technical staff of the Instituto Geográfico to convoke the municipal councils and, in agreement with them, to draw up the official documents containing the boundary lines. Finally the Instituto Geográfico staff made a 1:25 000 scale map of each municipality. This time the process was a success.

Figure 1. Landmarks

From 1910 to 1930, the Instituto Geográfico (now IGN) worked on the Catalan municipal boundaries and maps. The "actas" (the legal documents) were drawn up, boundary traverse surveys were observed and municipal maps were made.

## 3. SCANNING THE DOCUMENTATION

Today the 1910-1930 boundary documentation is kept in the Instituto Geográfico archives in Madrid.

The Catalan Statute of Autonomy approved in 1979 meant the transfer of power concerning municipal boundaries from the Spanish to the Catalan government.

The Institut Cartogràfic de Catalunya which was created in 1982 took on the technical responsibilities.

In 1988 the ICC scanned all the boundary documents and took pictures of every map in the IGN archives in Madrid. 7 366 documents (93 535 pages) were scanned and 3 268 pictures of maps were taken.

## 4. THE DOCUMENTATION

The documents in which the boundary line information is stored are:

- the territorial records ("actas")
- the field notebooks containing the land survey records
- the planimetric maps

The "actas" (territorial records) are the legal documents which contain the municipal boundaries. They are descriptive documents in which the landmark shapes and locations are detailed. They are signed by the municipal authorities.

The land survey notebooks contain the boundary traverse surveys (angles and distances) and describe the landmark locations numerically. The angles were plotted with compasses and the distances with stadia rods. This fact determines the degree of accuracy of the traverse data (quarter degree for angles and metres for distances). Some sketches complete the numeric data.

The municipal planimetric maps represent the cartographic documentation resulting from the boundary surveys undertaken at the beginning of the 20$^{th}$ century. In these can be found the landmarks, the boundary lines and other traverse surveys which show geographic elements such as paths, rivers, villages, etc. The ICC has geo-referenced all these old maps.

## 5. BOUNDARY PROBLEMS

Copies of the documents and the maps were sent to some of the municipalities. But, as many municipal archives were burned during the Spanish Civil War and also due to the political regime change in 1939, municipalities today are unaware of these documents and the precise definition of their boundaries.

This is the reason why, often, the "de facto" limits have been those shown on the cadastral maps, and these do not always coincide with the ones legally in force according to the territorial records ("actas").

On the other hand, the huge territorial transformations, which have taken place in Catalonia over the last 40 years, have meant that many of the landmarks have disappeared. We can still find 60% of them in rural areas but only 10% in the area around Barcelona.

The generalized use of digital maps and Geographic Information Systems, has highlighted the need to ascertain the precise boundary lines between the Catalan municipalities.

For this reason, the Catalan Autonomous Government has ordered the ICC to carry out with the whole technical work, with the aim of ascertaining the precise delimitations of the Catalan municipalities starting from the territorial records still in force.

This is the essential step previous to embarking on updating the Catalan municipality boundaries.

## 6. CATALAN MUNICIPALITY BOUNDARY PROJECT

The documents describing boundaries are: the territorial records ("actas"), the land survey notebooks and the planimetric maps. With these documents as a starting point, the ICC carries out the certification of every boundary line in Catalonia in order to know the precise location of the landmarks and the boundary lines.

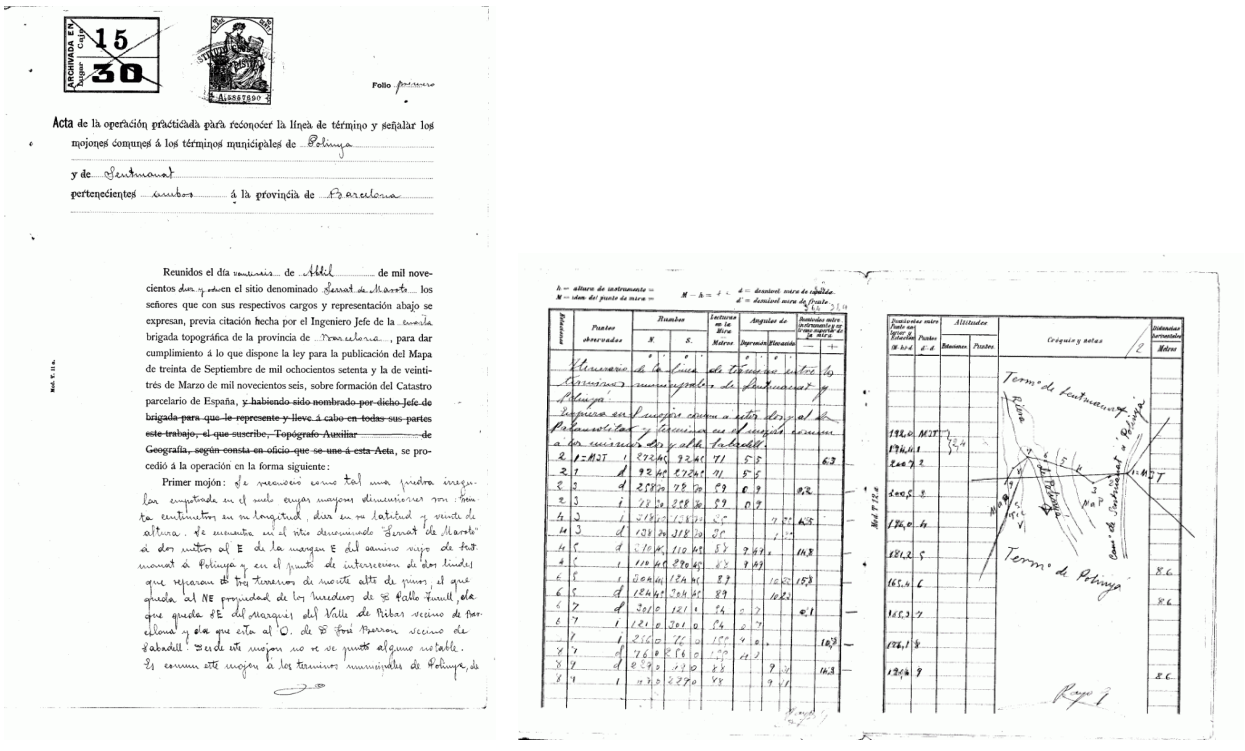

Figure 2. Territorial record and land survey notebook page

In fact, today, the ICC technical staff follow a similar process to that of the Instituto Geográfico used 90 years ago when remaking the boundaries.

## 6.1 Old topographic triangulations data input and calculations

The old municipal triangulations were part of the geodetical and topographical triangulation network observed at the beginning of the 20th century to make the municipal 1:25 000 scale maps. The boundary traverses connect the topographic points of these triangulations. Recalculating the old geodetic-topographical triangulation network allows us to have the first geo-referenced match of the old boundary traverses.

These local triangulations are in planar coordinates and the coordinates' origin is different for each municipality. Because we have the coordinates of the old geodetic network of 1910 we can adjust the local triangulations to this global one. The ICC has made a software program to convert these local triangulations to the UTM coordinate system. We need to start with a point in the local triangulation which coincides with its corresponding point in the old geodetic network.

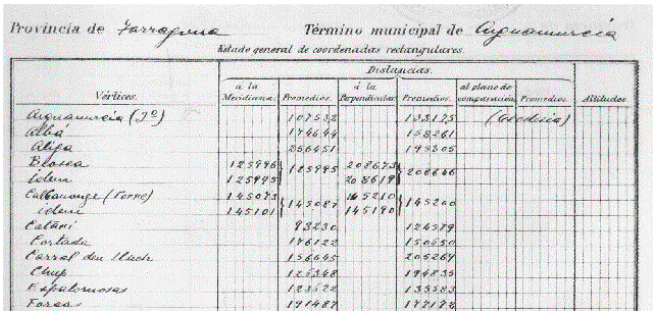


Figure 3. Local triangulation. Aiguamúrcia municipality

Today 60% of the local topographic triangulations are matched in the global geodetic one.

After this, a new process calculates the entire network again to find a better match among the local networks.

Although the final result is precise enough, it is important to remember that it has been determined according to the degree of accuracy of the old data. We must also remember that these triangulations were observed to make 1:25 000 scale maps.

## 6.2 Data input of the old boundary traverses

After local triangulations have been matched, the next step is to input the traverse data contained in the survey notebooks.

The numerical data in the survey notebooks is not homogeneous: different topographic instruments were used to collect field data, different observation methods were applied and the format of the notebooks was not always the same.

This data also contains observation and transcription errors. Because they were handwritten in the countryside, and because these documents are so old, their readability is always poor.

To make this process easier, the ICC has produced a new software program in Visual Basic language. It can detect a high percentage of errors by comparing the numerical data. If the application detects an error, an alert message comes up.

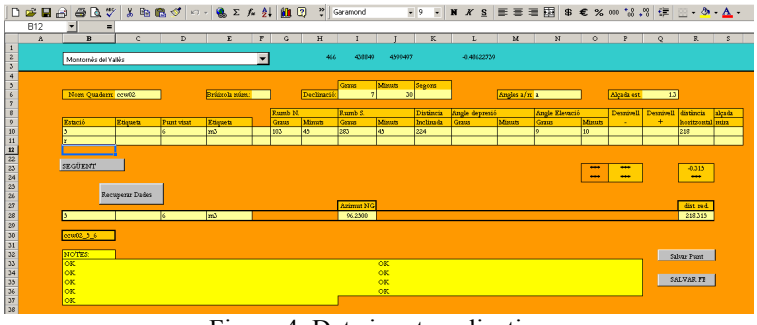


Figure 4. Data input application

### 6.3 Field work preparation

The numerical data input is saved in txt format files.

After data input, it is possible to calculate the boundary traverses and geo-reference them approximately. The resulting process file contains approximate UTM coordinates of the traverse points and landmarks.

The traverse data, which describes the boundary lines, is drawn on ArcPad (ESRI). With this software, we continue our certification work. This software allows you to visualize the calculated traverses over present-day maps, visualize the old geo-referenced planimetric maps, match our position from the received GPS data, gather GPS data, and calculate new data, etc.

After the data has been prepared, and the present-day maps have been loaded on our pen-tablet computer, we are ready to start our fieldwork.

### 6.4 Field work

With the first rough landmark position, we navigate using the GPS receiver, to the theoretical point where we expect to find the landmark. This is to verify whether the physical landmark is still there.

When there are no data problems, landmarks which still remain in place are found within a 20 meters radius from the theoretical position given in the first traverse match.

Precise UTM coordinates are given to landmarks which have been found with GPS receivers. The receivers used are Trimble Pathfinder XRS, GEO XT or similar. These receivers have sub-metric accuracy and are able to receive real time differential corrections by radio or by satellite. Today the ICC has implemented the VRS which allows us to improve the degree of differential correction accuracy.

Figure 5. Field data collection

When the landmark cannot be found, we must determine whether this is due to errors in the old traverse data or to our inaccurate first traverse match, or simply because the landmark is not physically there today. In the first two cases, we need to analyse the previous work to solve the problem.

When a landmark is not physically present and in order to define where it was located, we need to collect other data such as other landmarks, houses, intersection paths, etc. also defined in the old traverses. We then calculate the correspondent traverse area between these points to determine the missing landmarks position.

GPS data collection and some ArcPad scripts allow us to work on these calculations directly with the field computer (pen-tablet). No office work is needed.

Figure 6. Field work pen-tablet

The precise coordinate points are collected by real time differential GPS, or by post process differential GPS when real time is not possible.

The ArcPad software and some programmed scripts allow us different GPS point collection. We can also save GPS data for post processing (Trimble's GPS Correct is needed), make traverse adjustments, and codify pictures, etc.

All documentation scanned can be consulted on the pen-tablets it the field. While we are collecting field data, we can also entering boundary data into the data base. In this way we can enter landmark measurements, pictures, potential observations and the boundary line between a present landmark and the previous one.

### 6.5 Problematic boundary work

Finally we analyze the collected data in order to either give the final OK or continue working on it when necessary.

To continue studying problematic boundaries we can use another old document i.e. the internal traverses of the planimetric map. These traverses help us when there are problems with the boundary traverse data.

The internal traverses give us complementary information. They define geographical elements (roads, paths, rivers, etc.) shown on the planimetric map. These traverses sometimes have their starting or finishing point at a boundary traverse point. This makes a continuous network which allows us to use them to find landmarks.

The notebooks containing the internal traverses can be also found at the Instituto Geográfico archives in Madrid. We only use them for problematic boundaries. The same work method as in boundary traverses is used. When survey data has been entered and calculated, further fieldwork is needed to get new information to position all landmarks accurately.

Another important aid we use is aerial photography. It can help us to determine old paths or houses. The oldest photogrametric flights over Catalonia date from the late 50s.

### 6.6 Final tasks

The final traverse adjustments allow us to draw the definitive certificate boundary line over a 1:5 000 scale orthophotomap. The final boundary line is adjusted to the legal document description.

The final precision in the physical landmarks which have been found are sub-metric. Where landmarks cannot found, precision is obviously conditioned by the old compass and stadia rod precision used to observe the old traverses.

## 7. QUALITY CONTROL

Once all the data has been collected and calculated, and the certificated boundary line has been drawn, the ICC controls the work quality.

The whole project is then checked. The correspondence between the line described in the legal documents is checked against the one finally drawn over the present-day map. The calculations are also checked.

Some GPS measurements are used to check the general precision of the whole work.

## 8. BOUNDARY DATA BASE. DOCUMENT MANAGER.

All the information generated during the certification process is entered into the boundary data base. This is called ADLGis.

ADLGis is an ArcView extension programmed by ICC for managing and working with the boundary data.

The functions of this software are:

- To display the boundary lines over different scale maps
- To display and print the old documents
- To display and print calculations and proceedings
- To query municipal boundary lines
- To query landmark coordinates
- To show pictures and landmark position sketches
- To print boundary lines over 1:5 000 scale orthophotomaps
- To calculate municipal areas and perimeters, etc.

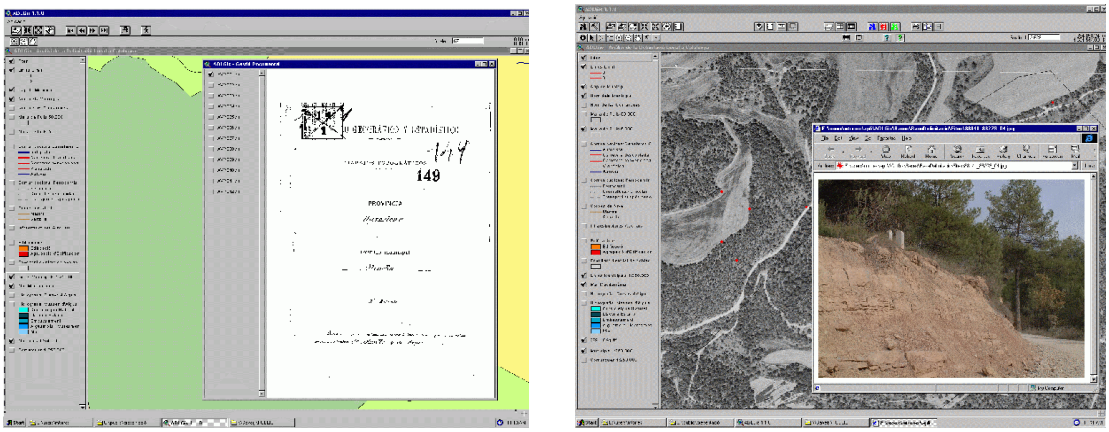

Figure 7. ADLGis screenshots

To input and elaborate all this data, the ICC has produced another application: BDManager. It is another ArcView extension.

### 8.1 The final document: the certification

ADLGis software automatically generates the final document from the data on the boundary base. We call this document certification. We can generate both soft and hard outputs.

The final certification contains:

- the description of the proceedings
- the landmarks coordinate list
- every landmark file, which contains the picture, the coordinates, the sketches, etc.
- the 1:5 000 scale orthophotomaps where the whole boundary between two municipalities is drawn.

## 9. THE MUNICIPAL MAP OF CATALONIA

Certificating all the present Catalan boundaries is an essential first step for the Catalan Autonomous Government, but it is not the last one.

Once we know the old boundary lines that are still effective today, the Catalan Autonomous Government technical staff (from Direcció General d'Administració Local) begin meetings with the municipal councils to find out whether it is convenient to update the boundaries and modifying them if required. We must remember that a hundred years have

passed from when the old legal boundaries were defined, and that over the last 40 years, Catalonia has undergone important geographic transformations, especially near the coast.

If in the end, it is agreed that a boundary needs to be modified, a new "acta" is drawn up and signed by the municipality councils. If necessary, new landmarks are installed. The ICC gives coordinates to these new landmarks. After all the boundary lines of one municipality have been certificated and/or updated, the ICC makes the official municipal map.

## 10. FINAL CONSIDERATIONS

The global delimitation of all Catalan municipalities is an essential task to guarantee the efficient working of our municipal and autonomous administration.

In order to implement this global project, today the ICC involves several branches in the field of cartography: Geographic Information Systems, GPS receivers, differential corrections (by radio, by satellite, net solutions), pen-tablets, PDAs, digital maps, etc.

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## BIOGRAPHY OF THE PRESENTING AUTHOR

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