

# **Community of representatives of geodetic-cartographic-cadastral services of Central Europe**

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Geodesy, Cartography and Cadastre Authority of the Slovak Republic

## **Accuracy and content of cadastral maps**

### **Introduction**

The Slovak Republic's area is about 49 000 km<sup>2</sup> (square kilometres), which represents about 7.3 million actually existing plots in the cadastre registered as so called the C-register parcels. Ownership documents exist for 5.7 million plots, which means that 78% of all C-register parcels the ownership relations have been registered in a standard, desired way. The remaining 1.6 million plots positionally correspond to approximately 8.2 million parcels, so called the E-register parcels. These are actually non-existent on the ground, because, due to historical and political development of the state, they were in fact merged into larger agricultural or forestry units or due to other reasons their configuration on the ground changed from their original registration (the original registration was administered mostly in the land registry book). To the mentioned 8.2 million E-register parcels the ownership relations have also been practically restored and have been registered on the ownership documents as ownership or administration to E-register parcels.

### **Historical boundary accuracy of E-register parcels**

Regarding the registering accuracy of E-register parcel boundaries we can say that at places where they are identical with the boundaries of C-register parcels the accuracy is logically the same. Elsewhere, the accuracy generally corresponds in terms of global accuracy to imperial scale maps from before 1927. Thus at mechanical transformation into the national reference system (S-JTSK) the accuracy of the detailed break points ranges from 0 to 5 m. It should be noted, however, that by analysing and with the current reasoning of all available documentation we can achieve much higher real accuracy. At the same time for about 1/7th of the Slovak territory the vector images of E-register parcels are made on the basis of paced out sketches without any scale. The identification of such parcels to the state in the field (or to the state in C-register) is problematic and we practically cannot speak of specific accuracy of such E-register parcels not even when based on the application of qualified estimation.

### **Historical boundary accuracy of C-register parcels**

More important than historical parcel accuracy of the temporary E-register, is the accuracy of boundary registration of real C-register parcels. Concerning this accuracy are the constitutional provisions of real estate protection and fair tax collection. Technical and therefore legal security for

registering of the subject of the law is unambiguously and permanently derived from it, which in this case is a plot determined by its boundaries registered with socially satisfactory accuracy.

The state of positional accuracy of boundary registration depends not only from the variety of accuracies of cadastral maps in individual cadastral districts, but also from the gradually evolving surveying accuracy and portrayal of updated content of cadastral maps and therefore pursuant to valid legislation the accuracy of boundary registration of each specific plot and therefore each individual break point is of importance.

In terms of dividing the original cadastral maps into imperial and metric it can be stated that 33.9% of the territory was originally mapped for the cadastral purposes in the imperial scales (especially at scale 1:2880) in Hungarian coordinate systems. Following the adoption of the Cadastral Act no. 177/1927 Coll. on Land Cadastre and its further management the mapping thereafter was carried out only in decadal scales in the metric system and so the remaining 66.1% of the territory has been mapped after 1927.

This 66.1% of Slovak territory can be divided as follows: 12.1% of the territory was mapped in the interwar period in a solid quality according to the so-called A-Manual. 14.6% of the territory was mapped according to the THM (technical and economic mapping) methodology without calculating of the final coordinates, valid until 1971. Between 1971 and 1986, 16.4% of the territory was mapped according to the THM methodology, with calculating the coordinates of detailed boundary break points. After 1986, the remaining 23% of the territory was successfully mapped, of course with documented coordinates of detailed points and just these are the cadastral maps of the highest internal quality in terms of accuracy and required content. All these cadastral measurements with documented coordinates of the points were measured mostly in the third, sometimes (forest units with the use of photogrammetric methods) in the fourth class of accuracy. This represents the basic mean coordinate error of 0.14m (or 0.26m) to the nearest points of geodetic control. Nowadays, to all detailed break points determined in coordinates by means of terrestrial methods applies the positional criterion of  $1,7 u_{xy}$  in relation to the position of a point determined by means of GNSS and transformed from geocentric coordinates of ETRS89 system into the S-JTSK system which is used by the real estate cadastre. This acceptable deviation of original terrestrial measurements is therefore set to 0.24m and when exceeded the obligation of correcting such coordinates in a defined way comes into force.

### **Present day - application of the ÚGKK SR Decree no. 87/2013 Coll.**

By amendment no. 87/2013 Coll. of the ÚGKK SR Decree no. 461/2009 Coll. implementing the Act of the National Council of the Slovak Republic no. 162/1995 Coll. on real estate cadastre and registration of ownership and other rights to real estates (Cadastral Act), as amended, a new categorization of accuracy was adopted, characterizing the quality of every detailed break points of cadastral maps, the origin of point determination, the coefficient values for calculating the extreme deviation of parcel area and the coefficient values for verifying the accuracy of point portrayal. A ground-breaking attribute of this legislative amendment lies in the fact that it surpassed the previously established view of cadastral districts as a single territory with homogenous accuracy of cadastral maps. At the same time a view of all previous non-numerical cadastral maps was reconsidered and we started to work with them as with partly numerical maps.

The decree de facto has defined a unified direction for surveying and documenting of surveying works and the results have been taken over to the real estate cadastre. The essence of new comprehensive technology of cadastral map administration is the connection of a precise method of plot boundary surveying, related calculations for documenting of the unambiguous position of these points and comprehensive way of creating and updating a vector cadastral map. The technology allows for the first time in the history of the cadastral management the incorporation of precise surveys of plot boundaries carried out solely in the European Terrestrial Reference System (ETRS89), of which there are about 60,000 per year, their unambiguous documentation in the national reference positional system used for cadastral surveys since 1928 (S -JTSK) and their implementation to the valid cadastral maps of any quality i.e. into the latest maps, as well as into maps in cadastral districts that were mapped in Hungarian historical systems in the 19th century.

A two-step transformation process was fixed: ETRS  $\leftrightarrow$  JTSK03  $\leftrightarrow$  JTSK with the aim of allowing the use of GNSS, so that each newly surveyed point could be at any time exactly reconstructed in the field and at the same time without undesired (mathematically inexpressible) deformation incorporated into the vector cadastral map. To ensure the functionality of the system our agency (ÚGKK SR) drafted an amendment of generally legally binding legislative regulations and a whole series of related technical regulations. Within this framework we have developed and since 30.01.2013 made publicly available a departmental transformation service which enables among other things to build the transformation ETRS  $\leftrightarrow$  JTSK03  $\leftrightarrow$  JTSK directly into a GNSS receiver. At the same time a free download of a corresponding conversion interpolation table directly into any PC was allowed.

In 2013, one of the first important application steps of the technology in question was an adoption of a new file categorization of vector cadastral map (VKM) together with the analysis of their quality. The quantification of that categorization up to March 2015 is as following:

- 1,816 files of numerical vector cadastral map (VKMč) - a set of maps with accuracy acceptable for the Cadastre and created mainly after 1971 (they precisely portray about 3.5 million plots in the national reference positioning system).
- 477 files of non-numerical vector cadastral map with implemented numerical results of measurements (VKMi); these are maps that respect the current method of their updating, while their precision allows the integration of new most accurate measurements and the current content of these maps adapts to these surveys during their updating.
- 1,863 files of non-numerical transformed vector cadastral map (VKMt), whose content due to its precision does not allow a direct integration of new measurements as it is in the case of VKMi files, but to each such map a specific adopted measurement file (SPM) is updated, into which accurate measurements without unwanted distortion are inserted. At the same time there is a presumption of future redefinition of some portion of VKMt onto a non-numerical VKMi. (The second and third group of files show together about 3.8 million plots).

Altogether, cadastral maps comprise 4,156 files (one cadastral district - one VKM file, exceptionally two VKM files) of vector cadastral maps.

On 15.01.2015 a validity of the final vector cadastral map was declared (containing C-register parcels). For the correct vector and full content shape it is still needed to complete about 1/3 of vector maps of determined documentation (VMUO) containing E-register parcels.

Until 01.05.2013 the cadastre registered the quality of a cadastral map only collectively for the entire cadastral district. Since then, there has been an obligation to register corresponding quality code for every detailed break point.

Quality code	Detailed point quality
T=1	Numerically determined point in the S JTSK according to § 55 section 4 ( $m_{xy} = 0.08\text{m}$ ( $m_{xy}$ - mean coordinate error))
T=2	Numerically determined point in the S JTSK with no real denotation in the field; this code cannot be used in the case where the point denotation in the field is necessary or where the detailed point has already been denoted in the field ( $m_{xy} = 0.08\text{m}$ )
T=3	Numerically determined point in the S JTSK using terrestrial geodetic methods without being connected to active geodetic control ( $m_{xy} = 0.14\text{m}$ )
T=4	Numerically determined point in the S JTSK using terrestrial geodetic methods without being connected to active geodetic control ( $m_{xy} = 0.26\text{m}$ )
T=5	Non-numerically determined point; coordinates of the point were determined cartometrically (mean coordinate error without distinction of accuracy).

Application of Decree no. 87/2013 Coll. has enabled the incorporation of newer correct surveys without local mathematically unidentifiable transformation even to non-numerical VKM (which was not possible before). This process has been progressing well and for the implementation of this task it is necessary to analyse and correctly incorporate about 500,000 measurements carried out mainly through the creation of survey sketches (GP) into the VKM and into the SPM. The results so far (two years of work) speak for themselves. In this way since 01.05.2013, the number of parcels with boundaries determined in the VKM with satisfactory accuracy has increased from 3.5 million to 4.3 million of all C-register parcels. This represents an increase from 48% to 60% of the parcels registered directly in the VKM with satisfactory accuracy. According to estimates, this number can be documented in coordinates into VKM increased up to 68% -70% after supplementing of all previous measurements. During monitoring of the increase of detailed points registered in the VKM with satisfactory accuracy it represents an increase from about 24 to 30 million points registered in suitable accuracy class. Currently, about 22 million non-numerical detailed points remain in the VKM.

When mentioning the satisfactory accuracy we have in mind the accuracy defined by basic mean coordinate error of 0.14m and better. This corresponds to the already-mentioned maximum positional deviation of 0.24m (when comparing the coordinates of the original terrestrial measurements with the coordinates determined by means of the GNSS).

Number of parcels according to the VKM as of 28.02.2015

Number of parcels in the VKMč (numerical vector cadastral map)	3 505 164
Number of numerically determined parcels in the VKMi (non-numerical vector cadastral map with implemented numerical results of measurements)	470 387
Number of numerically determined parcels in the SPM (adopted measurement file)	354 167
Aggregated number of numerically determined parcels (satisfactory accuracy)	4 329 718
Aggregated number of non-numerically determined parcels	2 975 232
Aggregated number of C-register parcels	7 304 950

Number of detailed points as of 28.02.2015

Number of points in the VKMč (numerical vector cadastral map)	24 118 327
Number of numerically determined points in the VKMi (non-numerical vector cadastral map with implemented numerical results of measurements)	3 754 252
Number of numerically determined points in the SPM (adopted measurement file)	2 536 877
Aggregated number of numerically determined points (satisfactory accuracy)	30 409 456
Aggregated number of non-numerically determined points	22 135 058
Aggregated number of points in the SGI KN (cadastral geodetic data file)	52 544 514

### Survey sketches

Survey sketches play a vital role in the cadastral map updating. Survey sketches are a part of cadastral geodetic data files that represents the technical foundation of legal acts, public documents and other documents that serves as a basis for lodgement and entry of rights to real estates. Survey sketches are drawn up on the basis of surveying results. Survey sketches contain mainly graphical representation of properties before and after the change indicating old and new parcel numbers, nature of land use and their areas, as well as data on rights to properties.

The annual number of officially verified survey sketches in Slovakia has long oscillated around 60,000. A vast majority of them return to the real estate cadastre within 12 to 36 months as document annexes and by this way boundaries of about 200,000 plots, which are mosaically distributed throughout the whole of Slovakia, are determined with satisfactory accuracy. In absolute terms this corresponds to about 100 cadastral districts. This processing of survey sketches is in the majority paid for by the individual owners and legal entities.

The accuracy of surveying works used for creation of the geometric plans is the same as the one used for new mapping.

### **New mapping in built-up areas**

is methodologically and technologically prepared, but due to the lack of financial means is currently carried out only sporadically.

To the content of a cadastral map created during the renewal of cadastral documentation by new mapping belong the state borders, the boundaries of territorial and administrative units, municipal boundaries, cadastral district boundaries, urban zone boundaries, boundaries defined by the right to real estate (ownership rights ...), nature of land use boundaries and the boundaries of protected realities. Further, the content of a cadastral map consists of buildings that a) are a subject of the cadastre, and b) are not a subject of the cadastre, but are a subject of the base map (for example water constructions and facilities, road constructions and facilities, energy buildings and facilities, industrial buildings and facilities and others). The part of the cadastral map content, which is not a subject of the cadastre is also not a subject of subsequent updating of the cadastral map, therefore the content of the cadastral map in this part always diverges more and more from the actual state in the course of time.

The accuracy of surveying works and final coordinates of detailed points is set by the accuracy characteristics and accuracy criteria. The accuracy characteristic of the x, y coordinates of detailed point determination is the basic mean coordinate error  $m_{xy}$ , which is set by the formula

$m_{xy} = \sqrt{0,5 (m_x^2 + m_y^2)}$ , where  $m_x$  and  $m_y$  are the basic mean errors of x, y coordinate determination.

Relative accuracy characteristic of determining a pair of point coordinates is the basic mean error  $m_d$  of the length  $d$  which is a direct connecting line of these points calculated from the coordinates. Coordinates of detailed points are determined in a way so that

a) the characteristic  $m_d$  does not exceed the criterion  $u_{xy} = 0,08m$ ,

b) the characteristic  $m_d$  does not exceed the criterion  $u_d$  calculated for each length  $d$  from the formula  $u_d = 0,12(d + 12)/(d + 20)$ .

### **New mapping in non-built-up areas**

Due to a huge fragmentation of ownership shares and plots as such, new mapping in non-built-up areas without a simultaneous implementation of land consolidation makes no sense. Therefore, the new mapping currently takes place only within the land consolidation under the Act no. 330/1991 Coll. of 12 July 1991 on land consolidation, land ownership arrangement, land offices, land resources and land communities. The essence of land consolidation is rational spatial land ownership arrangement in certain territories and other immovable agricultural and forestry real estate associated with it performed in the public interest, in accordance with the terms and conditions of environmental protection and creation of territorial system of ecological stability, functions of agricultural land and operationally-economic aspects of modern agriculture and forest management and rural development support.

Map content and mapping accuracy are the same as at new mapping in built-up areas.

## **The future of cadastral maps**

The objective is that the detailed break points of all boundaries and all buildings that create the content of cadastre, have been determined with a fixed homogeneous accuracy in a numerical vector cadastral map in the C-register, to which will be in the full range (to all plots and to all buildings) entered the ownership rights. E-register (that means the vector map of determined documentation) will be moved to the archive. To achieve overall satisfactory accuracy the following steps must be taken:

- non-numerical transformed vector cadastral map (VKMt) and adopted measurement file (SPM) merge into non-numerical vector cadastral map with implemented numerical results of measurements (VKMi)
- non-numerical vector cadastral map with implemented numerical results of measurements (VKMi) will be gradually mapped to numerical vector cadastral map (VKMč), and in justified cases, it will be mapped to numerical vector cadastral map (VKMč) directly from the adopted measurement file (SPM)

Note: mapping of the remaining number of plots whose boundaries are not registered by the cadastre with satisfactory accuracy, will be carried out selectively and only in the built-up areas (in the non-built-up areas the only rational solution is the implementation of land consolidation projects). Under the selectivity we mean boundary measurements of such plots which are registered without relevant coordinates and to which the rights are entered in the C-register. Repeated and publicly funded surveys of plot boundaries, which have already been surveyed with sufficient accuracy when creating survey sketches, and paid for by individual owners, is hardly justifiable.

We consider the utmost stabilization of cadastral content and hence the facts concerning the mapping of plots as extremely important.