RESEARCH ON THE COMBINED USE OF GPS - TOTAL STATION SURVEYING TECHNOLOGIES IN CADASTRAL AND ENGINEERING WORKS

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ABSTRACT

During the period 2015 – 2023, extensive national works are being carried out within the framework of the National Cadastre and Land Book Plan (PNCCF). In view of this, the research team from the Faculty of Agronomy in Craiova tried to achieve a simple, rapid and accurate procedure for terrain surveying with modern methods, using total station and GPS technology. The use of a total station was necessary since, even if topo-geodetic surveys performed with a GPS are faster and yield greater return, engineering works necessitate a high precision, which can only be fulfilled by combining the two technologies. It also made possible to verify the precision when determining new points in the support network built for this case. In order to achieve the proposed objectives, a complex building with a more complex composition from Craiova was studied, topo-cadastral elevations being accomplished using high-precision equipment, the efficiency of a total station (Trimble S6 servo) and GPS (Trimble R10), which from a technical point of view enabled us to achieve the best results in the most rigorous of cadastral works, carried out at a national or even international level. The results obtained from the methods and technologies, applied both on the ground and in the office work, as well as the calculation of the coordinates and the support network compensation are very relevant, precise and with high efficiency, making the proposed solutions to be of a real interest for terrestrial measurement experts at the local, national or even international level.

INTRODUCTION

The subject of the paper belongs to the second category of topo-geodesic works. As such, the works are usually accomplished on more narrow areas than those in the first category (when we usually refer to the map or basic topographic plan draw on different scales), and the features of the topographic works are strongly influenced and sometimes even imposed by the desired technical purpose. The methods and tools used in the special topographical works lead to differentiation from classical works, leading to a new branch of terrestrial measurements with its own object: "engineering topography" or "applied geodesy" (Bădescu et al., 2009, Călina et al., 2015).

The field work was carried out in a well-defined logical sequence, starting from the recognition of the work area, the establishment and marking of sewage caps, and the collection of data by appropriate measurement methods. The fieldwork results served as initial data for the office work. According to the provisions of the enforced technical instructions, the network of base points is determined in the Stereo' 70 planetary reference system, and the Black Sea altimetric reference system 1975 (Şmuleac et al., 2017, Călina et al., 2018). This can be achieved by using the existing network state geodetic points in the area as points for the support network.

The main topographical elements explored in this paper are the field measurements (angles, distances, level differences) with which a certain common or special objective is transposed on the topographic plane (Burghilă et al., 2016, Călina et al., 2014). To achieve the proposed objectives, the following preliminary works were achieved: - topographic surveying networks were developed by plane and levelling topographical works, up to the designated object and geometric elements were established to define the position of the objective in space. After this problem was solved, the topographic dimensions of the planimetric and levelling positioning of all the details were identified: - the topographic elements of the elevation were determined by the number and nature of the topography, geometry and correct construction of the objective: - the degrees of precision materialized on the ground was established and the levelling network was implemented, the topographical elements determined and the outline of the measurements was drawn; structural data or any other technical details were collected.

MATERIAL AND METHOD

The purpose of the topographic documentation is to build a 1:250 scale plan for the property located in the central area of Craiova, located in the centre of Dolj County. More specifically, on the administrative territory of Craiova, at the intersection of Calea Unirii Street and Voinicului Street, at an altitude that ranges from about 70 m to about 85 m above sea level, due to the relief of the studied area.

To accomplish the work, the routing method supported on the starting point or the routing method in closed circuit was used. This was done because on the surface to be levelled only one known coordinate point was identified from the state geodetic network and two older points in the vicinity with which the orientation was accomplished. The details that were paramount to be levelled were measured by the radial method, because the support points previously determined by the traverse method were in their vicinity, which allowed them to be determined in the best conditions. Level differences and point elevation calculations to determine ground terrain were measured concurrently with the planimetric elevation, thus greatly reducing execution time and considerably increasing the yield of topographic elevations.

Given the theme of the paper, there were field and office activities that resulted in the elaboration of the writing, as well as the drawing necessary for the elaboration of the topographic documentation. Completing the field and office work, with access to the measurements and the intermediate and final results of their processing, the documentation related to the work was prepared, according to the enforced technical instructions (Kovyazin et al., 2014; Marian, 2012). The technical documentation for the paper has analog and digital format components and contains the following; Written parts - Coordinate inventory, - Technical memo, Methods of work; Drawings: - situation plan at a 1:250 scale.

The operations that were performed for all methods of levelling the support network and field details complied with the following conditions: - maximum distance from support point to characteristic point of 100 m; - the number of points measured from a station does not exceed 100 m; - the measurement of the characteristic points realised in a clockwise direction, starting from the base support in both positions of the telescope; - the first visa and the last visa will be towards the point of support; - measurements for each characteristic point (horizontal angle, pitch angle, inclined distance).

RESULTS AND DISCUSSIONS

In order to present the modern, accurate and efficient methods that can be used in the field of terrestrial measurements in Dolj County and at a national level, the working team studied the building located at Aleea Voinicului, No.14, (formerly no. 10), Craiova, Dolj county (Fig. 1), for which it was necessary to draw the site and delimitation plan for the design of construction works.

Figure 1. Location of the building in the area

Regarding the performance of topographic surveying activities, it is necessary to create a grid and levelling network, using measurement technology, with the Trimble S6 servo total station, by the closed traverse method combined with the polar coordinates method. In terrestrial measurements, technologies of the type described in the paper are mainly used in global geodetic networks, topographic networks, cartography and engineering topography, but also in cadastral work. Networks determined by the total station are constrained by the need for visibility between points and do not allow a large distance between points when compared to GPS.

In the design and land recognition works, it was intended that the points to be included in the network should meet a number of favourable criteria for determining with the total station (Şmuleac et al., 2017, Călina et al., 2015): - the materialization of the points to ensure their stability and preservation over time; - the points have a free horizon; - access to points is convenient and possible by means of a car; - choosing the position of the points does not raise problems with their use, at any time and by any user, or because of the owner of the land on which they are located.

Measurements can be made in the daytime, in any season, regardless of weather. Considering the particularities of the area, namely the configuration of the land and the terrain from the UAT Craiova, it was necessary to plant eight new points. To beginning the works, it was required to specify the area of interest first. To establish the ownership boundaries of the area of interest, a record of all the neighbouring cadastre, location and delimitation plans, ownership boundaries, inventory of coordinates from OCPI Dolj was obtained, following a request for information.

At the documentation stage, it was essential to study an old map, execute the land recognition, identify the geodesic points in the area of interest, the known coordinate points previously used in other works in the area, the contour surface, support points and levelling points in the plane. The objectives of land recognition are the following: - positioning of geodetic points, determination of exact position and height of geodetic signals, identification of triangulation points, establishment of organizational measurements. At the end of this stage of land recognition, a scale outline was drawn, containing all the elements that exist physically in the field and can be recognized. If a plan or map of the levelling surface is not available, the land recognition is made, and a plot of the land and the topo-cadastral elevation project are drawn.

The levelling network, consisting of nine station points, starting from a known coordinate point with orientation on the other two known points, acquired from the Office of Cadastre and Real Estate Advertising; these are geodetic points in the Craiova network and are considered as old points (Table 1).

Table 1.

Coordinates of old points used to build the support network

Landmark no.	Coordinates		Altitudes (Z)
	X	Y	
P 336	312258.305	404221.148	76.90
P 337	312390.416	404197.063	77.65
P 338	312462.052	404167.731	78.16

The levelling method used was the closed traverse combined with the polar coordinates method, starting from the known coordinate point named P337, from the O.C.P.I database and closing at the same starting point of known coordinates (Fig. 2). The works started at P337, pointing to P336 (geodetic point), followed by S100 station, followed by S4, S3, S1, S2, S101, S102, S103 and closing again on P337, with P338 orientation, all the visas between the stations were given in two positions Position I, respectively II. These have been verified by GPS measurements with the Trimble R10 receiver. A topographic survey carried out were an advantage because in this way buildings with sporadic land cadastral documentation and books can be checked. As a result of the determinations accomplished, physical changes in the field of the constructions and annexes were found, which lead to their updating by the sporadic cadastral works. All the data collected in the field was recorded in the total station's land register (Table 2), allowing it to be downloaded into the computer, processed and reported with special programs.

Table 2.

Legend name points by codes

Code Point	Meaning	Code Point	Meaning
Cc	Construction corner	C	Canal
Pg	On the fence	Sc	Scale
Ma	Alley edge	Cr	Corner ramp
P	Parking	Crj	Corner ramp down
Cp	Corner Parking		

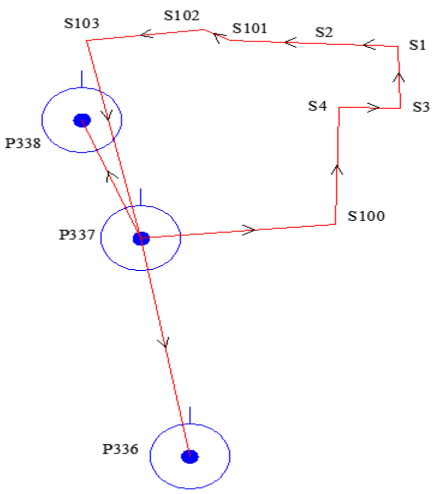

Figure 2. Outline of the support network

Table 3.

Calculation of closed planimetric traverse

Station point	Target point	Distance	Provisional orientation	Final orientation	Cos θ / Sin θ	Relative coordinates ΔX	Relative coordinates ΔY	Absolute Coordinates X	Absolute Coordinates Y	Point
P337	P336	134.28		188.5199	-	-	-	312390.416	404197.063	P337
	S100	96.67	94.2598 +32^{cc}	94.2630	0.089994 / 0.995942	8.70	96.27 +0.01	312399.104	404293.211	S100
S100	S4	70.89	1.7840 +64^{cc}	1.7904	0.999604 / 0.028119	70.86 -0.01	1.99	312469.953	404295.204	S4
S4	S3	30.34	100.9335 +96^{cc}	100.9431	-0.014813 / 0.999890	-0.45	30.33 +0.01	312469.503	404325.546	S3
S3	S1	37.15	397.4229 +128^{cc}	397.4357	0.999188 / -0.040269	37.12 -0.01	-1.50	312506.627	404324.053	S1
S1	S2	28.43	302.4235 +160^{cc}	302.4395	0.038310 / -0.999265	1.09	-28.41	312507.724	404295.637	S2
S2	S101	54.83	302.9529 +192^{cc}	302.9721	0.046668 / -0.998910	2.56	-54.77 +0.01	312510.302	404241.024	S101
01	S102	14.19	331.5377 +224^{cc}	331.5601	0.475687 / -0.879614	6.75	-12.48	312517.064	404228.543	S102
102	S103	58.93	292.7169 +256^{cc}	292.7425	-0.113753 / -0.993508	-6.70	-58.54 +0.01	312510.306	404169.955	S103
S103	P337	122.92	185.8438 +280^{cc}	185.8718	-0.975475 / 0.220108	- 119.90 -0.01	27.06 +0.01	312390.416	404197.063	P337
P337	P338		375.2276 +3.12^{cc}	375.2588						P338

Σ=515.14 m ΔX = +0.03; e ΔY = -0.05

Choosing the compensation method is a very important operation in terms of the accuracy of determining the relative and absolute coordinates of the points. Due to errors in the angles and distances measurements, the orientation transmitted from the tramline to the triangulation point directions was not equal to the calculated orientation from the coordinates (Table 3), and the coordinates of the closing point obtained from the routing calculation were the same as the original coordinates. Therefore, it is necessary to compensate for these non-closures. Compensation can be done through rigorous or non-rigid methods, depending on the required precision and the form of the network (Table 3). Non-rigid methods generally provide the necessary precision and rigorous methods are the subject of geodesy (Muellerschoen et al., 2000). In the case of non-discretionary compensation, three cases are distinguished, namely (Sui, 2014): compensating the crossbars and polygons supported by triangulation points; compensation of a network with nodal points; compensation of complex networks.

The compensation method is chosen according to the shape of the network and the points on which it is based. $T\theta = 50^{cc}\sqrt{N}$; N – number of stations, 50^{cc} - instrument precision.

$$Tc = 0.003\sqrt{Dt} + \frac{Dt}{2600}$$

Dt - total traverse distance

The processing of data gathered by modern technology implied the downloading of observation files after which they were converted into special formats that can be loaded into calculation and compensation software. Subsequently, the coordinates of the surveyed points in the official system of Romania - Stereographic Projection System 1970 - were calculated, starting from points: P336, P337, P338 located in the area of the site, using the TopoSys software, the points obtained after the final processing contain data information on the planimetry and levelling elements used for drawing by the AutoCad platform of the site layout.

The calculation and compensation of station points and radiated points were performed also using the TopoSys 5.0 calculation software, with following steps: (Fig. 3, 4 and 5). Verification with the help of the software was done to increase the accuracy of determination of the new points and to make it easier and faster to draw the site and delimitation plan from the coordinates of the points generated by the program. This solution was chosen as only the support points have been verified, the points of detail being determined only in the software, and they are not used in other topographical surveys because their position cannot be verified by precise methods.

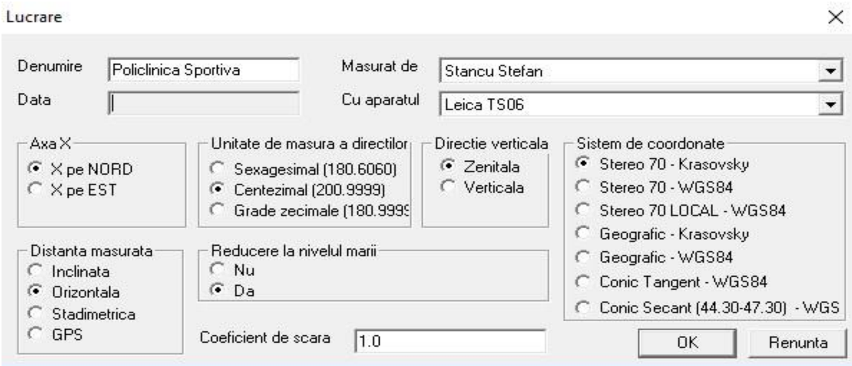

Figure 3. TopoSys 5.0 program setting

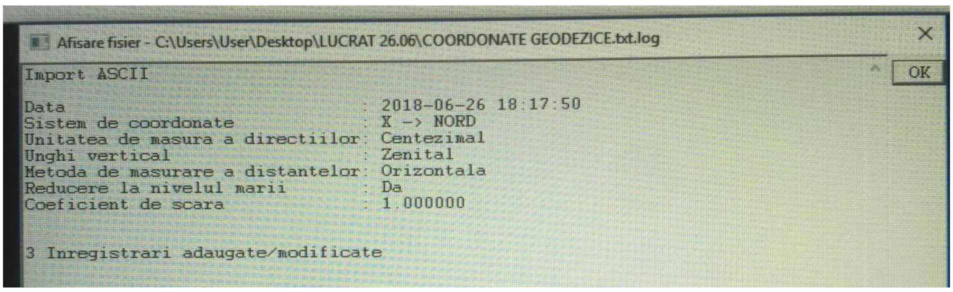

Figure 4. Entering known points

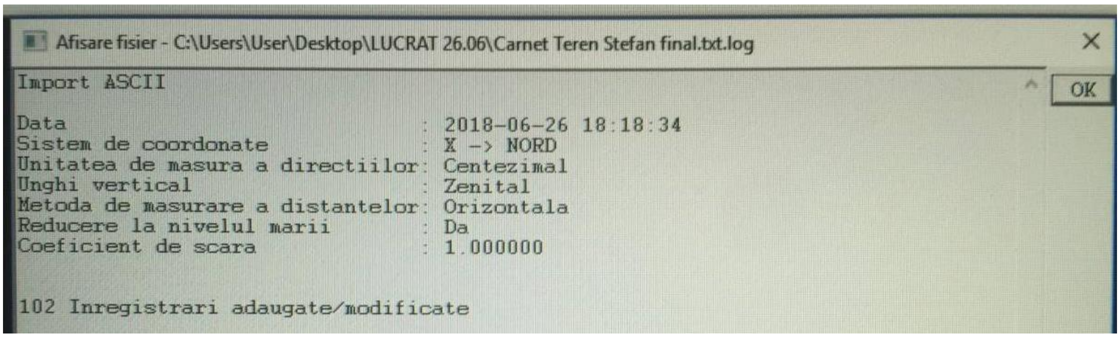

Figure 5. Entering radiated points

Determination of the X, Y, Z coordinates of the detail points was made by measuring the distances between the station point and the radiated point and their directions; the altitudes were calculated by means of the vertical angle, by trigonometric levelling. Using horizontal distances and detail point directions, their relative coordinates were calculated, based on which the absolute coordinates were determined in Stereographic 1970 system (Table 4).

Surface calculation is performed to know the area of a territory or property; the surfaces can be calculated based on field data (distances and angles) based on the elements measured on the plane (distances and angles) or the rectangular coordinates of landmarks (Olinic and Olinic, 2016). Calculation of surfaces by the analytical method, depending on the absolute rectangular coordinates is the most accurate method of surface determination (Table 5).

Table 4.

Coordinates inventory

Point no.	Coordinates			Point no.	Coordinates		
	X (m)	Y (m)	Z(m)		X (m)	Y(m)	Z(m)
S102	312517,064	404228,543	77,83	38	312470,241	404338,681	81,21
S3	312469,503	404325,546	81,41	39	312477,549	404336,311	81,49
S101	312510,302	404241,024	77,95	40	312478,474	404336,247	81,50
S2	312507,724	404295,637	82,10	41	312477,358	404334,680	81,50
S1	312506,627	404324,053	81,82	42	312478,304	404334,542	81,50
S4	312469,953	404295,204	81,13	43	312477,938	404335,437	81,54
P336	312258,305	404221,148	76,90	44	312479,627	404331,511	81,47
P337	312390,416	404197,063	77,65	45	312468,932	404331,645	82,09
P338	312462,052	404167,731	78,16	46	312466,605	404323,998	81,48
S103	312510,309	404169,955	77,75	47	312471,345	404322,412	81,55
S100	312399,104	404293,211	82,75	48	312472,191	404322,390	81,61
1	312476,967	404321,400	81,69	49	312464,291	404309,362	80,40
2	312476,926	404321,110	81,75	50	312471,009	404308,205	81,86
3	312505,931	404320,810	81,77	52	312481,378	404308,267	81,42
4	312505,965	404309,670	81,75	53	312486,033	404310,113	82,00
5	312508,491	404314,799	81,77	54	312488,339	404301,828	81,35
6	312507,444	404314,665	81,78	55	312491,733	404301,873	81,29
7	312507,417	404322,058	81,84	56	312491,978	404301,225	81,27
8	312507,950	404331,364	81,85	57	312470,885	404300,879	81,23
9	312507,379	404331,369	81,83	58	312470,495	404301,480	81,18
10	312497,289	404331,466	81,65	59	312466,995	404301,574	81,29
11	312496,856	404337,853	82,21	60	312464,127	404301,420	81,35
12	312484,439	404326,531	81,78	61	312461,841	404294,665	81,29
13	312481,251	404321,980	81,69	62	312464,751	404294,101	81,21
15	312476,944	404322,786	81,61	63	312456,692	404301,232	81,47
16	312423,579	404311,810	83,43	64	312475,054	404296,920	81,09
17	312473,474	404322,792	81,61	65	312474,195	404294,142	81,07
18	312473,418	404321,441	81,66	66	312473,013	404293,298	81,07
19	312473,372	404315,444	80,62	67	312484,440	404293,439	81,23
20	312472,049	404315,399	80,55	68	312483,150	404294,728	81,19
21	312471,162	404315,398	79,94	69	312473,372	404314,316	82,15
22	312458,940	404331,829	79,94	70	312496,263	404309,742	82,05
23	312472,181	404313,403	80,56	71	312503,186	404309,673	83,05

24	312472,145	404310,636	80,07	72	312506,581	404308,105	81,57
25	312473,335	404309,923	80,40	73	312506,969	404304,116	81,50
26	312471,297	404310,645	81,47	74	312508,276	404303,984	81,68
27	312467,515	404314,837	81,39	75	312508,243	404302,793	82,10
28	312467,737	404319,825	81,47	76	312507,066	404302,039	81,45
29	312467,418	404329,880	81,50	77	312508,908	404302,108	82,29
30	312468,259	404322,804	81,47	78	312518,094	404302,183	82,88
31	312464,225	404320,194	80,75	79	312519,722	404301,270	83,19
32	312464,055	404323,321	81,30	80	312520,924	404295,386	83,11
33	312463,966	404326,585	81,39	81	312520,025	404294,352	83,07
34	312468,476	404326,592	81,45	82	312510,058	404297,273	82,26
35	312469,333	404330,544	81,38	83	312505,254	404301,999	81,99
36	312476,884	404326,527	81,56	84	312496,404	404294,916	81,42
37	312464,344	404338,817	80,53				

Table 5.

Surface calculation

No. of points	X [m]	Y [m]	No. of points	X [m]	Y [m]
36	312464.179	404330.856	2	312476.961	404321.245
37	312464.368	404338.981	15	312476.979	404322.922
38	312470.275	404338.820	17	312473.510	404322.926
94	312474.056	404338.744	18	312473.454	404321.573
11	312496.892	404337.987	19	312473.415	404315.554
10	312497.325	404331.596	69	312473.408	404314.478
9	312507.416	404331.497	25	312473.380	404310.004
8	312507.987	404331.491	53	312485.745	404309.954
5	312508.522	404314.935	86	312485.741	404311.654
77	312508.933	404302.236	87	312488.441	404311.637
95	312508.371	404302.229	88	312488.444	404310.537
76	312507.086	404302.212	89	312488.344	404310.537
83	312505.255	404302.187	90	312488.346	404309.937
55	312491.764	404302.009	91	312491.176	404309.919
54	312488.370	404301.964	92	312491.171	404311.491
96	312473.447	404301.766	93	312496.301	404311.505
58	312470.525	404301.616	70	312496.306	404309.885
59	312467.025	404301.711	71	312503.205	404309.830
60	312464.155	404301.558	4	312505.996	404309.797
49	312464.315	404309.514	3	312505.965	404320.937
31	312464.237	404320.311	Surface = 357 m^2; Parcel: C1		
32	312464.087	404323.458			
33	312463.999	404326.723			
Surface = 1539 m^2; Parcel: ground					

After the completion of the measurements made on the ground and the processing of the data, a 1:250 scale plane was drawn, on the A3 format paper, belonging to the building, at the address: Aleea Voinicului, No.14 (formerly no. 10) Craiova, Dolj County. The plan will be accompanied by the inventory of coordinates and technical memo. The situational plan was processed in a digital format in AutoCad 2014, where the coordinate inventory was reported, after which the points were merged, by codes. The plan containing heights was also achieved. The building that is the subject of this documentation has the use category: - 1Cc - with a total area of 1548 square meters and measured at 1539 sqm. On the ground there is construction: C1 - Sport Policlinic with the height regime, Sc = 357 sqm, Sd = 738 sqm, construction system: brick, sheet metal.

The graphic representation of the planimetric details was achieved with conventional signs comprised in the conventional sign atlas edited by M.A.I.A. in 1978 (Figure 6).

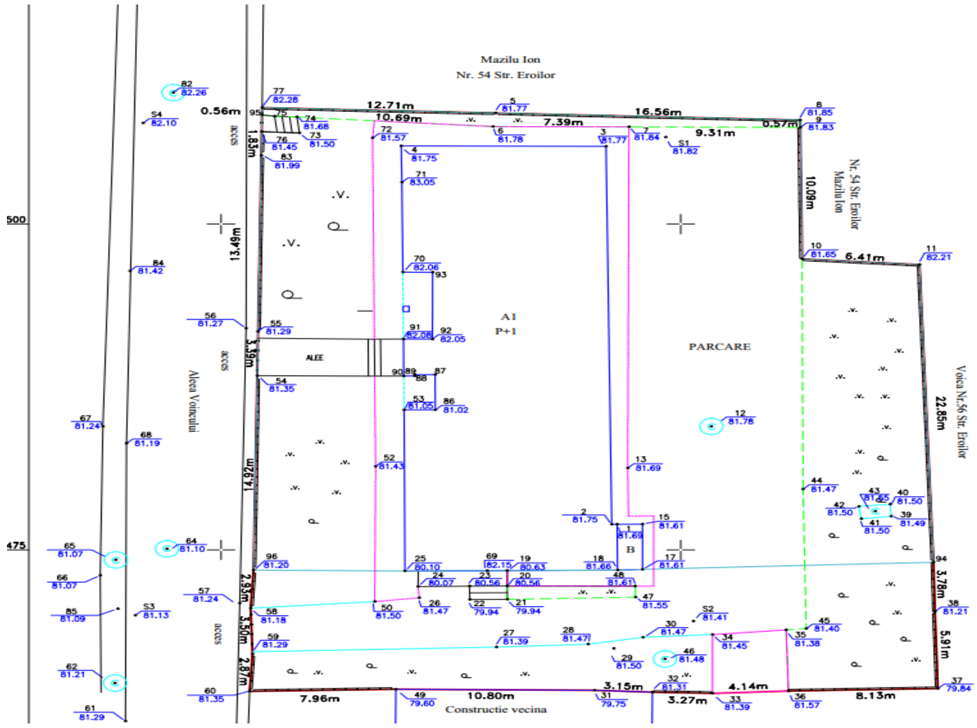

Figure 6. Location and delimitation plan

CONCLUSIONS

The work accomplished was desired to be employed within the Stereographic Reference System 1970, based on the coordinates of the geodesic points taken from the maps and topographical plans from the support coordinate inventories made available from the ANCPI and OCPI Dolj database respectively and that the data obtained complied with the requirements and standards of precision and rigor imposed at national level.

During the course of the research, the methods applied both on the field and in data processing were to be as modern and accurate as possible, so that a series of valuable and useful results could be obtained at the end for all the terrestrial measurement specialists. For this purpose, cutting edge topographic equipment was used in field work that provided us with superior precision and efficiency compared to other instruments in the same class of the older make. Also, using the combined GPS – total station method, we found that the two processes have near-precision, but efficiency was much higher when using GPS technology.

The valuable results obtained through the use of this technology, especially with regards to the efficiency and effectiveness of cadastral work, which we have concluded in the over 25 years of experience in the field of land surveys, gives us the necessary expertise and confidence to recommend the use of GPS technology in the General Cadastre works to be carried out within the PNCCF, with the exception of the use of older equipment, to ensure the accuracy and quality standards imposed in such works.

In terms of construction and engineering works, for topo-cadastral elevations made for designing and layout, it is necessary to use the high-performance total stations for the collection of data and the processing of primary data to be done on a computer, with specialized software programs to ensure the possibility of rigorous verification of the data obtained. Only through post-processing of all the data recorded in the field on the total stations is it made possible to obtain precise positions of the points in terms of planimetric and levelling, which fully satisfy the precision requirements and rigor imposed in the case of construction and engineering works. We also found that the best results from the point of view of the precision and verticality of the topography elements, necessary for construction and engineering works, are obtained by using the total stations, which was also noted by American specialists in the field (Muellerschoen et al., 2000; Wübbena et al., 2001).

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