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Prof. Dr. sc. Murat MEHA
Chief Executive Officer
Kosovo Cadastral Agency
akk_kca@yahoo.com
Archive Building 2nd floor
Tel. +381 38 512 353; Fax 356
Mob: +377 44 120 958
Prishtine, Kosovo
E-mail: mmeha@yahoo.com

1. INTRODUCTION

Since the existing terrestrial network in Kosovo was considerably damaged and there is no document regarding quality and adjustment of the network, building of a new homogenous modern network based in the world systems like WGS84, EUREF etc by using modern equipment like GPS and Total Station, was necessity.
Kosovo for a long time since 1912 was under Yugoslavia. Therefore all geodetic measurements and surveying was done by rules accepted as in other territory of Yugoslavia. Official map projection for Yugoslavian territory- it means also in Kosovo was accepted in 1924 Gauss - Krüger conformal transverse cylindrical projection of three- degree meridian zones.

Starting from Greenwich meridian to the east, Yugoslavia was covered by the 5th, 6th and 7th zones having the meridians of 15, 18 and 21 as central meridians. Each zone encompasses 3 of longitude, which means that it spreads 1,5 degrees to the left and 1,5 degrees to the right from the central meridian. Kosovo is covered by 7^{th} zone respectively by 21^0 central meridian. The 7th zone with central meridian 21^0 spreads from $19^0.5$ to $22^0.5$.

Defined ellipsoid for that area was used Bessel ellipsoid (1841) with the following parametres:

$$a = 6\ 377\ 397.15500\ m,$$

$$b = 6\ 356\ 078.96\ 325\ m$$

$$f = 1: 297.0000$$

and scale reduction at the central meridian by 0.0001 (scale factor 0.9999)

So, the main objective is establishment of Reference Network according to the European system EUREF for the needs of all measurements activities in survey, cadastre GIS, mapping, etc.

2. COORDINATE SYSTEMS

2.1. Rectangular coordinate system

Each rectangular co- ordinate system in the plane of the Gauss - Krüger projection has its origin in the intersection point of projections of central meridian and the equator. The plane rectangular co- ordinates used in practice are called "reduced co- ordinates" to stress the scale reduction at the central meridian by 0.0001. Furthermore, a constant value of 500 000 was added to all ordinates in order to avoid negative signs.

The Kosovo network was homogenous, but some points are not within reach for people because of mine-contaminated areas during recent war. The actual status of the points (1st and 2nd order) was unknown; there is no inventory (condition of the pillars or plugs) of the first or the second order points, little documentation about the way of adjustment or the quality of the network available etc.

General needs was to set a modern reference network based on ETRS89 and the former Yugoslavian triangulation network to transform for the needs of surveying, cadastre, GIS and construction in Kosovo.

2.2. Height System

Height system in Kosovo is based on the point defined referring system to the mean Adriatic sea level in Trieste (Molo Sartorio). That point is establish since 1872. derived from long observation. These data defining the first height system – normal orthometric (spherical) which is used in Kosovo. First systematic works on the geometric leveling at the territory of Yugoslavia (and Kosovo) were from different institutions by The Military Geographic Institute from Vienna than from Austro-Hungarian Monarchy, from Russian institute and from the Military Geographic Institute from Belgrade.

Within the new works on the geometric leveling, the field revision of leveling lines in the Austrian precise leveling was made in 1946-1960 at the territory of Yugoslavia. A new leveling named II leveling of high accuracy - IINVT - was carried out in the period between 1970 and 1973. This leveling was supposed to be used for the establishment of a new height system, and it comprised the territory of the entire former Yugoslavia. These benchmarks served as the basis for all fundamental and practical works on the geometric leveling in the period afterwards. The measurements of the IINVT were carried out exclusively with the levels WILD N3, Invar centimeter staffs with double scales, and by using leveling survey arrows instead of slippers.

For the connection to orthometric heights the inbound of a selection of leveled, former reference points of the IINVT system is needed. In a further step, this allows to compute, in combination with a first approach calculation model, a dataset of a minimum, tiny geoid in Kosovo for GPS kinematic purposes

Also the more correct computation of transformation sets for projections including rotations caused by the orthometric heights of the reference points will be possible.

3. KOSOVAREF01 Network

3.1. New 1st Order Reference Network

Reference network 1st order called KOSOVAREF01 consists of 32 stations measured by KCA applying static method of GPS measurement with LEICA 500 SYSTEM. Experts of Swiss Federal Office of Topography have done the computations.

In order to integrate the observations in Kosovo into the European Reference System (ETRS89) and the European Reference Frame (ETRF) respectively, the GPS observations of the following tracking stations of the EUREF Permanent Network (EPN) were included in the data processing:

Name	ID	Country	Operating since	ETRF97 coord. known?
Bucharest	BUCU	Romania	11.02.1999	No
Dubrovnik	DUBR	Croatia	22.09.2000	No
Graz	GRAZ	Austria	12.06.1993	Yes
Matera	MATE	Italy	17.02.1992	Yes
Ohrid	ORID	Macedonia	20.07.2000	No
Osijek	OSJE	Croatia	18.09.2000	No
Sofia	SOFI	Bulgaria	19.05.1997	Yes
Zimmerwald	ZIMM	Switzerland	01.09.1988	Yes

Table 1: List of the European reference stations used for KOSOVOREF01

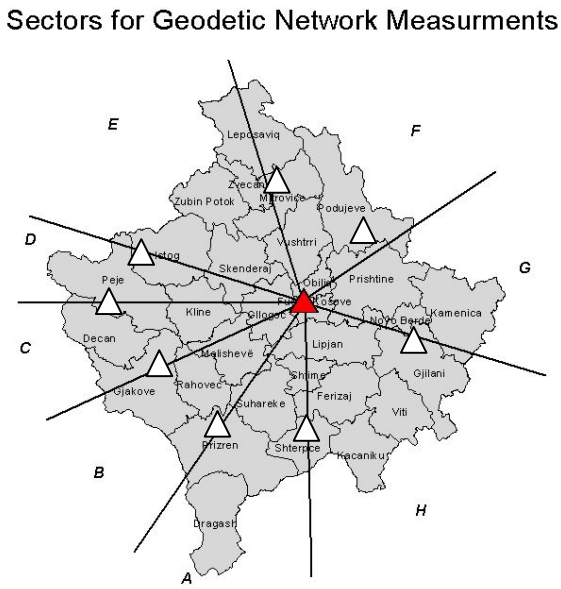

Fig.1. Kosovo territory in 8 sectors

It was analyzed Kosovo territory to be in 8 sectors and station **FK01** fig.1. would serve as the reference station in Kosovo observed on a daily basis. The network was established homogeneously over the whole territory of Kosovo. It is adjusted with the observed points of the EUREF Permanent Network (EPN). The rest of the stations were observed at least on two different days or on four different days if they served as nodal points between two regions.

3.1.1. GPS observations

The GPS observations in Kosovo were carried out between March 20 and April 12, 2001. The Kosovo Cadastral Agency (KCA) staff in cooperation with international staff organized and made

well the whole measuring campaign with very clear purpose to reach best possible results high accuracy and reliability. The observation sessions were carried out in the morning. The recommended 3 to 4 hours of observations could obviously not always be met. The epoch interval was 15 seconds and the minimum elevation 10 degrees. The campaigns fulfilled the following points:

Independence:	2 campaigns after 1.5 weeks
Measuring window:	Checked min. 5 Satellites by SKI PRO Almanac, GDOP<5
Measuring duration:	3-4 hours (1 station 2 hours only), static mode
Recording interval:	15 sec
Minimum elevation:	5 degrees
Station protocols:	See appendix 1
Sessions:	8 sectors with 3 reference stations, 3-4 new points. For the planning of reference stations see the sector map (▲, △: main and secondary reference stations).
Time needed:	8 sectors by 1 day > 16 days (20.03. -12.04.2001)
Personal resources:	3 teams with 2-3 GPS experts
Used equipment:	Leica GPS receivers 520 and 530 with **Leica AT502** antennas

The GPS data observed by these stations for the entire Kosovo campaign were downloaded from the local data centers in the RINEX format via FTP. The campaign started (18.03.01 = day **078**) until the last day of the campaign (11.04.01 = day **102**). The files are designated by an 8-digit number consisting of the 4 letters of the station ID, the 3 numbers for the day of the year as well as the session number 0 and the suffix .01O (for example: Zimmerwald for 18.03.01: ZIMM0780.01O).

3.1.2. Height observations

Totally 23 of 32 1st order reference network points were connected by GPS measurements to orthometric heights from 12 former FYR IINVT points. For the detailed selection see appendix 2. Because of the short baselines the final computation of the point coordinates was done with SKI PRO at Kosovo Cadastral Agency (KCA). All the leveling data was evaluated with Leica LevelPak at KCA. Outgoing from this results the height differences for measured 1st order reference network points was calculated as well as the final orthometric heights for all 1st order reference network points.

Designed homogenous distribution of 12 leveled height reference points over the area of Kosovo was more important and was taken into consideration a selection of 12 leveled FYR height reference points. The intention was to observe as many as possible of the 1st order points in combination with former height reference points. A maximum distance of 1st order network was of 15 km in relation to a former height reference point. 23 points of 1st order reference network points were connected by GPS measurements to orthometric heights from 12 former FYR IINVT points (For the detailed selection see appendix 2).

Before the measuring all points were checked according their quality (checklist) by local experts (KCA) to see possibility using existing points (see report of computations and results from the Swiss Federal Office of Topography, Berne).

Because of the short baselines the final computation of the point coordinates was done with SKI PRO at KCA. All the leveling data was evaluated with Leica LevelPak at KCA. Outgoing from this results the height differences for measured 1st order reference network points could be calculated as well as the final orthometric heights for all 1st order reference network points.

From the results shown in appendix 2 it can be seen that there was no general height shift detectable. The differences between ellipsoidal (WGS84 from GPS measurements) and orthometric heights form the leveling lay in the range of 44.190 – 45.620 m.

Only one of the former FYR IINVT points could be used directly as a GPS station. All the rest was measured by excentrum points. The excentrum points were connected by leveling to the FYR IINVT points.

Independence:	1 campaign
Measuring window:	Checked min. 5 Satellites by SKI PRO Almanac, GDOP<5
Measuring duration:	1-2 hours, static mode
Recording interval:	5 sec
Minimum elevation:	5 degrees
Station protocols:	See appendix 1
Sessions:	11 sessions with 2-3 reference stations.
Time needed:	11 sessions by ¾ day > 8 days, 5 days for levelling (28.06.-16.07.2001)
Used equipment:	Leica GPS receivers 520 and 530, Leica NA 3002

3.2. Geodetic Datum and Projection System

Based on that written before we needed to define the new geodetic datum for territory of Kosovo. The geodetic datum was defined with the establishment of the 1st order reference network KOSOVAREF01 as Gauss – Krüger projection on the European Terrestrial Reference System ETRS89 (GRS80 ellipsoid) as standard for new surveying systems in Europe. Therefore parameters are defined as follows:

Reference spheroid:	IUGG (International Union of Geodesy and Geophysics) ellipsoid GRS80 (Geodetic Reference System of 1980)
Reference system:	ETRS89 (European Terrestrial Reference System), connected to EPN (EUREF Permanent Network).
Origin:	In the intersection point of projections of central 21st meridian and the Equator. Height at origin: Adriatic Sea level.
Projection system:	Gauss-Krüger conformal transverse cylindrical projection (7th zone). Scale reduction at the central meridian (21st) by 0.0001 (scale factor 0.9999)
Vertical datum:	Determined for 03.07.1971 with average sea levels of the Adriatic

Sea over the period of 18.6 years in Kopar, Rovinj, Bakar, Split and Dubrovnik for the FRY leveling network called IINVT.

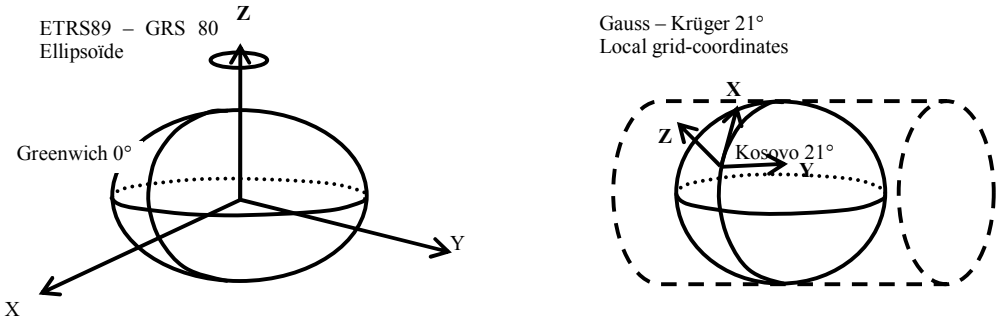

Fig.2. Ellipsoid and local grid coordinates for Kosovo

3.3. New coordinate system for Kosovo and comparisons with old coordinates

New coordinate system should be used for any further GPS observations, especially for densifying this network with 2nd and 3rd order network. This means that the Gauss-Krüger conformal transverse cylindrical projection (7th zone) is adopted, included the scale reduction at the central meridian by 0.0001 (scale factor 0.9999). But in contrast to the old Gauss-Krüger (GK) projection using the Bessel ellipsoid the new system is based on the IUGG ellipsoid GRS80 as used for instance in ETRS89. This ellipsoid has the following dimensions:

$$a = 6378137.0 \text{ m},$$
$$b = 6356752.3141 \text{ m},$$
$$f = 298.257222.$$

Link GPS stations as possible to the existing leveling network of Kosovo have been realized either by direct leveling of the GPS station or by short GPS baselines. As result the "levelled" heights of the GPS stations were compiled the GPS solutions with ellipsoidal heights. The differences between the ellipsoidal and the levelled heights theoretically should correspond with the geoidal undulations. The levelled heights GPS as well as the geoidal undulations given by the European Gravimetric Geoid 1997 (EGG97) [Denker and Torge, 1997] the resolution of EGG97 is 1.5 x 1.0 minutes. These differences are shown in the map of the geoid (Fig. 5.2). They are always smaller than 50 cm and they show some systematic behaviour. The differences can either be due to the geoid (offset and slight tilt), which might not be specific enough for these local studies, as well as due to errors in the levelling. The part of the differences originated in the ellipsoidal heights should be limited to some centimeters.

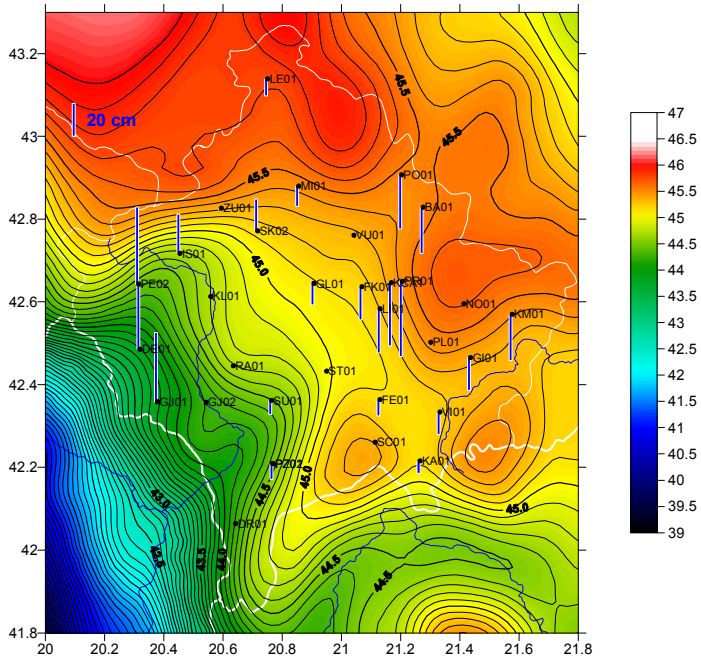

Fig.3. European Gravimetric Geoid EGG97 [by Denker] and the residual differences in height.

Nr.	Name	Geoid1	Nr.	Name	Geoid
01	BA01	45.4614	17	MI01	45.4358
02	DE01	43.7882	18	NO01	45.6055
03	DR01	44.2195	19	PE02	44.4368
04	FE01	45.1179	20	PL01	45.4325
05	FK01	45.1670	21	PO01	45.4778
06	GI01	45.3328	22	PR01	45.4263
07	GJ01	43.7765	23	PZ01	44.4498
08	GJ02	44.2103	24	PZ02	44.4496
09	GL01	45.0870	25	RA01	44.6886
10	IS01	44.6733	26	SC01	45.2954
11	KA01	45.1123	27	SK02	45.1401
12	KCA1	45.3395	28	ST01	44.9757
13	KL01	44.7027	29	SU01	44.4945
14	KM01	45.4098	30	VI01	45.1772

15	LE01	45.7240	31	VU01	45.2804
16	LI01	45.2013	32	ZU01	45.3194

Tab. 1: European Gravimetric Geoid EGG97 [by Denker] and the residual differences in height Geoid undulations.

In the transformation between the old coordinates and the new, GPS based coordinates, there are basically two ways to take care of these differences in heights: Either by calculating a local geoid or by considering at least the general offset and tilt within the transformation parameters. It was decided to go the second way. Therefore the coordinates (old Gauss-Krüger) and the levelled heights of 18 reference points (file KOSOVO.PK) were transformed in ellipsoidal heights using EGG97 and from there into relative geocentric coordinates X, Y, Z using the program GEOREF.
The determination of the 7 transformation parameters between the old and the new coordinate system was done using the program ATRA (see **Appendix 6** and **7**). Given the above mentioned file of old coordinates (transformed from GK) and the file of the same stations in the ETRF89 reference frame, the following transformation parameters were:

Translations: DX = 628.54052 m DY = 192.25380 m
DZ = 498.43507 m

Rotations: ALPHA = -13.79189 cc BETA = -.81467 cc
GAMMA = 41.21533 cc

Scale: S = -17.40368 ppm

(General remark: The definition of the parameters, e.g. the sign or the order of the rotations, may vary with the transformation software used. It's therefore recommended to test the results with the values given in Appendix 7).
The 32 GPS stations were then transformed into the newly defined Kosovo coordinate system, first with ellipsoidal heights and secondly, by applying the geoidal undulations of the European Geoid EGG97, with orthometric heights **Appendix 8**. It is the projection is still Gauss-Krüger but based on the GRS 80 ellipsoid.
Finally, as a quality check, these coordinates of the GPS stations directly derived from the ETRS89 coordinates (KOSOVO_ETRF.PK) were compared to the new Gauss-Krüger coordinates of the 1st order control points as transformed from their original GK coordinates using the above defined transformation parameteres The output in **Appendix 9** shows the good general agreement between the two data sets.
The "global" 7 parameter transformation is not able to care for local distortions. It should also be mentioned that the 7 parameters defining the transformation are strongly depending of the quality and representativity of the reference stations used. For instance the scale factor, now with the 18 stations found to be 17 ppm, was only 10 ppm using all GPS stations with old local GK-coordinates (but some without levelled heights).
The new geodetic reference frame KOSOVAREF01 is with high accuracy and homogenous and meets the requirements of a modern network (GRS80 Ellipsoid, Integration ETRF etc.)

The mean standard deviations of the coordinate component of the final solution KOSOVAREF01 (1st order reference network) are:

Easting	Northing	Ellipsoidal Height
$\sigma = \pm 2.5$mm	$\sigma = \pm 4.4$mm	$\sigma = \pm 8.7$mm

We want to thanks: Swiss Federal Office of Topography Berne, for the computations of transformation sets and a preliminary geoid data set; Swiss Company BSP + Partners; International and local colleges who works in this project.

[1] Kohli, A., Krasniqi, R., Heer, H.P., 2001. Reference Network 1st order KOSOVAREF, Project Report Nr 020-001, KCA, Pristina

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Appendix 1 – Triangle Definition File: TBP coordinates in FRYREF30 and KOSOVAREF01

Appendix 2 – Data Structure and Metadata of the Project

Appendix 3 – Residual of Checkpoints after Transformation with Definite Triangle Network

Appendix 1 EUREF Permanent Network, Standard Time Series, of the Tracking Stations

Appendix 2. Final Solution of the GPS Network Kosovo. (Printout of the the Program ADDNEQ) (File: KOSOVO.doc)

Appendix 6. Transformation of the stations withold Gauss-Krüger coordinates and levelled heights into relative geocentric coordinates X, Y, Z. (File GEOREF.GKaltCRD)

Appendix 7. Determination of the 7 transformation parameters from old to new coordinate system using program ATRA. (File ATRA7.PRN)

Appendix 8. Transformation of the ETRS89 coordinates into the new Gauss-Krüger coordinate system using program GEOREF. (File PROJNEU.PRN)

Appendix 9. Quality check: Comparison of the old coordinates (transformed into the new coordinate system) with the GPS-coordinates also transformed into the new coordinate system) using program TRANSINT (File TRANSINTneuGPS.PRN).

Supplement 1. Tracking Stations from the EUREF Permanent Network (EPN) General map per station (according to Table 2.1): Standard Time Series Station Log File.

1st order network of points in KOSOVOREF01 in Kosovo.

Pt ID	*E*	*N*	*Ellips. Height*	*Off. Height*
BA01	**7522538.4899**	**4743287.9845**	**689.3813**	643.7452
DE01	**7444008.5655**	**4705339.1564**	**566.3720**	521.7577
DR01	**7470424.2332**	**4658348.9977**	**1074.0462**	1029.7358
FE01	**7510693.7911**	**4691608.0842**	**659.6860**	614.4528
FK01	**7505655.2632**	**4721903.4453**	**584.7155**	539.4641
GI01	**7535883.9666**	**4702986.8964**	**640.0816**	594.6980
GJ01	**7448789.2401**	**4691172.1162**	**483.8429**	439.3449
GJ02	**7462263.3999**	**4690965.4467**	**450.1287**	405.6410
GL01	**7492360.1051**	**4722790.9038**	**663.1543**	617.9749
IS01	**7455299.0819**	**4730997.9218**	**482.6372**	437.6570
KA01	**7521916.4985**	**4675180.3008**	**806.6284**	761.7352
KCA1	**7513815.7362**	**4722984.6878**	**666.6692**	621.2127
KL01	**7463766.3843**	**4719366.5898**	**435.8681**	390.9481
KM01	**7547355.0754**	**4714667.3962**	**635.3978**	589.9740
LE01	**7479678.0664**	**4777723.3110**	**591.1666**	545.3140
LI01	**7510711.1187**	**4715992.0614**	**601.7465**	556.4610
MI01	**7488177.7770**	**4748913.2757**	**553.6998**	508.1782
NO01	**7533945.9861**	**4717396.7516**	**1042.7853**	997.3411
PE02	**7443799.0261**	**4722845.7405**	**542.6198**	497.8170
PL01	**7524785.9669**	**4707032.9016**	**1116.4928**	1071.2321
PO01	**7516606.1431**	**4751973.5156**	**691.4463**	645.9640
PR01	**7516877.2057**	**4723387.1649**	**856.0852**	810.7088
PZ01	**7480872.7897**	**4674458.6805**	**915.3459**	870.7796
PZ02	**7480871.9820**	**4674464.8566**	**913.6776**	869.1113
RA01	**7469954.2387**	**4700737.1683**	**1083.2466**	1038.4804
SC01	**7509395.8421**	**4680136.2366**	**891.2979**	846.4484
SK02	**7476821.1106**	**4736911.3506**	**759.5223**	714.3107
ST01	**7495882.2045**	**4699243.1873**	**1204.3037**	1159.3522
SU01	**7480558.6755**	**4691421.3503**	**532.5190**	487.7714
VI01	**7527422.4419**	**4688310.6695**	**537.1835**	492.1052
VU01	**7503454.2625**	**4735711.0908**	**620.4348**	575.0292
ZU01	**7466793.6787**	**4743077.6898**	**916.5042**	871.3037

A pillar of geodetic point in KOSOVOREF01 with other data.

AGJENCIA KADASTRALE E KOSOVËS — KOSOVAREF01 Rendi i I[rë]
KOSOVO CADASTRAL AGENCY — KOSOVOREF01 *1st Order*

Komuna, vendi i quajtur:
Municipality, place name Gllogoc

Kompleksi FERONIKEL/ FERONIKEL Complexes

Koordinatat Gauss-Krüger
Gauss-Krüger-Coordinates

Nr:GL 01

y	**7492798.8105**
x	**4722283.6025**
$h_{offic.}$	**617.9749**

Përshkrimi i pikave/ Lloji i monumentit
Points description / Monument type

Shtyllë betoni/Concrete pillar

Koordinatat GRS 80 Ellipsoid
Coordinates GRS 80 Ellipsoid

Long.	**20^0 54' 24.5937" E**
Lat.	**42^0 38' 41.2167" N**
h_{ell}	**663.1543**

Koordinatat në KOSOVAREF01
Coordinate in KOSOVAREF01

y	**7 492 360.105**
x	**4 722 790.904**
$h_{offic.}$	**617.9749**