GNSS support for bathymetry

Dumitru Paul Daniel, Ph.D, Lecturer, Technical University of Civil Engineering, Faculty of Geodesy, paul.dumitru@gmail.com
Calin Alexandru, Ph.D, Lecturer, Technical University of Civil Engineering, Faculty of Geodesy, alexcalin1975@yahoo.com
Plopeanu Marin, Ph.D, Lecturer, Technical University of Civil Engineering, Faculty of Geodesy, mplopeanu@yahoo.com
Badescu Octavian, Ph.D, Assoc. Prof., Technical University of Civil Engineering, Faculty of Geodesy, tavi.badescu@gmail.com
Badea Dragos, Ph.D, Lecturer, Technical University of Civil Engineering, Faculty of Geodesy, badea_dragos@yahoo.com

Abstract: *Today, the geodetic works for the realization of the hazard and risk maps have become increasingly important for hydrographical basins areas. The generation of the digital terrain model using classical measurements and modern technologies and its analysis are important steps in taking of important decisions on flood defence and prevention. An important element knows the shape and capacity of water retention in some lakes that are part of the studied hydrographical basin. In this paper is presented the methodology for the determination of the 3D shape of a lake using as support for the bathymetric sonar survey the GNSS/RTK real time observations. The ROMPOS system of ANCPI was used to make the kinematic measurements.*

Keywords: *bathymetry, GNSS, RTK, sonar, ROMPOS*

1. Introduction

One of the thorniest problems in the last period for which important funds were allocated was the achieving the risk and hazard maps in the watershed to prevent and mitigate the effects of flooding. In this respect, the role of geodesy in such works is very high and is crucial in achieving these maps accurately. Besides determining the shape of river basins are needed some bathymetry works for the existing rivers and lakes in basins. Also, an important element is the determination of the retention capacity of the lakes in the area of interest. To determine their three-dimensional shape there are accomplished works of bathymetry and function of the depths there are known many techniques and methods of measurement. One is represented by the use of sonar together with GNSS technology that leads to accurate determination of depths of the relevant lakes in the studied basin.

2. General considerations

In Romania the situation of natural hazards has become one of the most important environmental problems. Up to 2010 it is not known or not realized the risk and hazard maps for flood prevention and mitigation for any hydrographical basin. A national approach involves a large volume of work but also adequate costs. Making precise measurements necessary to produce such maps involve the use of modern techniques and technologies to ensure fairness and rapidity in carrying out such works. In particular, it is solicited 3D land topography for analysing the hydraulic models. Much of the 3D model could be done using

LiDAR techniques that cause high precision Digital Terrain Models, but a problem arises, given the characteristics of the technology, when you have to study lakes and rivers where there is water retention. To solve the problem it performs bathymetry works and taking account of the infrastructure, depth there could be used the appropriate methods and techniques. For determine the depths of a lake can use classical techniques a road and a total station to determine planimetric position but also modern methods by determining the depth using performance sonar with GNSS technology that provides superior results over classic technology.

3. GNSS support for bathymetry

In this paper we present a methodology for bathymetry works on a natural lake with a perimeter of 63 km, an average length of 14 km and an average width of 2 km. To determine the depth of the lake were realised sonar measurements concatenated with GNSS measurements made with a dual frequency receiver and connect to the national system for determining the position ROMPOS [3].

Previously was determined by static GNSS methods the bridging network in the work area, network used in the verification of real-time GNSS RTK.

The equipment used is represented by sonar Garmin GPSMAP 421s that has a dual frequency transducer (Fig. 1):

Fig. 1 Garmin GPSMAP421s sounder and TOPCON GR3 GNSS receiver.

GNSS receiver used is the Topcon GR3, the latest handset with NTRIP option and connection to ROMPOS.

The Garmin GPSMAP 421 is a compact chart plotter that features an ultra-bright 4” QVGA colour display along with an improved high-speed digital design for increased map drawing and panning speeds. It’s ready to go with a built-in, satellite-enhanced worldwide base map and an easy-to-use interface designed to help you navigate the open waters with ease. The Garmin GPSMAP 421 also accepts Blue Chart g2 Vision cards for added features and functionality such as high-resolution satellite imagery, 3D views and Auto Guidance technology.

The Garmin GPSMAP 421 base map contains worldwide satellite images in place of traditional maps. The Garmin GPSMAP 421 also comes standard with a high-sensitivity GPS receiver for superior satellite tracking and quicker acquisition times. And with an SD card slot, it's easy to add additional maps without connecting to a computer.

The sounder version, GPSMAP 421s, comes with a powerful dual-frequency transducer that clearly illustrates depth contours and uses a dual frequency transducer 50kHz (45°), 200kHz (10°) for maximum performance. The GPSMAP 421s are also NMEA 2000-certified for easy connectivity with sensors and instruments.

Knowing the contours of the lake, the measurements will be performed prior in cross section (transversal) profiles and they were designed according to the technical specifications of the beneficiary. Given the length of the lake as well as the fact that are no large variations of depths, the cross sections profiles were projected at an interval of 500 m, resulting in a total of 42 profiles. It has also been designed and a longitudinal profile which besides its usefulness in the depth mapping was also used to verify the results, intersecting each transversal section (Fig. 2).

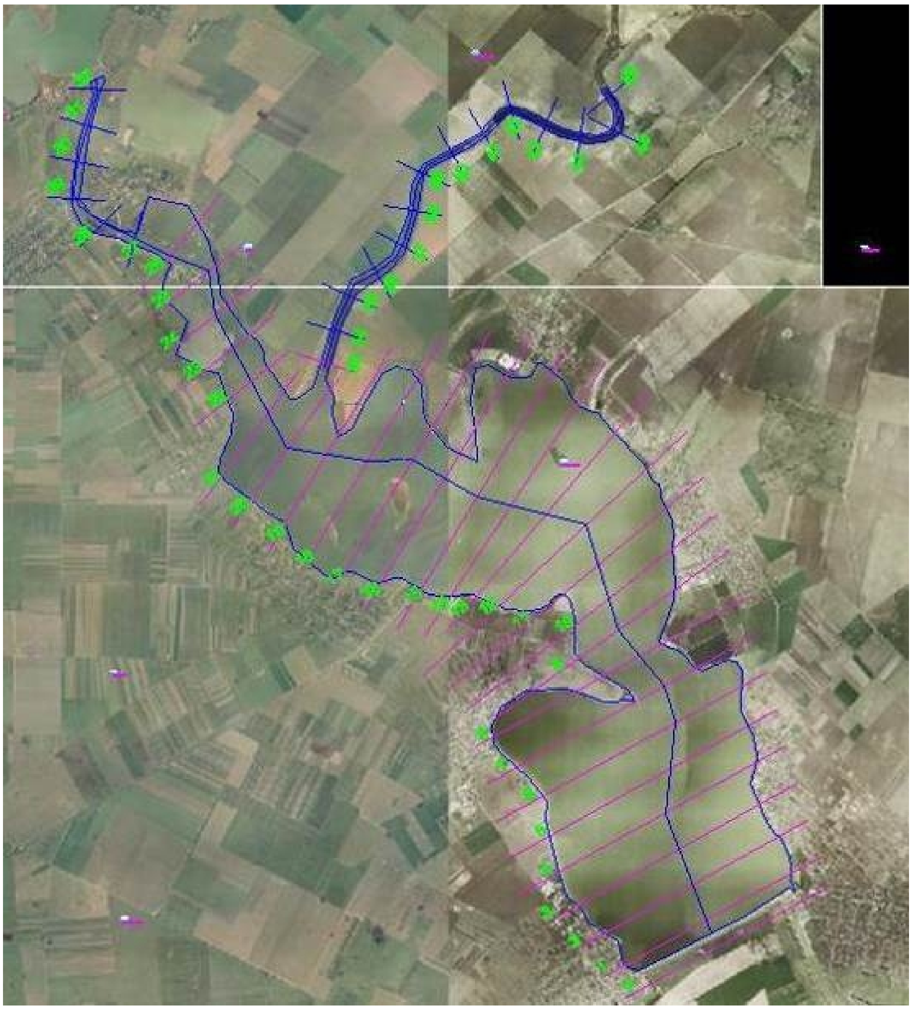


Fig. 2 The projected transversal and longitudinal profiles.

This project has been loaded into the controller so that the measurements could be performed according to the design.

Both sonar and GNSS receiver were mounted on a specially built on a boat (Fig. 3):

Fig.3 Equipment mounted on boat.

Bathymetry as planned the team made measurements of depth with sonar and ellipsoidal coordinates using GNSS technology. To achieve real-time kinematic measurements was used ROMPOS RTK service, real-time determinations with fixed solutions and a positioning accuracy of ± 2 cm (Fig. 4).

Points | Lines | GPS Occupations | **GPS Obs** | Codes

Point F...	Po...	Start Time	D...	dN (m)	dE (m)	dHt (...	Hori...	Verti...	Distanc...	Solution Type
Base1	S04	4/23/2012 10:42:10 AM	00:01:00	0.336	-0.708	3.816	0.002	0.002	3.896	Fixed,Phase Diff
Base2	S05	4/23/2012 10:47:21 AM	00:01:00	-13178.401	-2096.411	-30.900	0.002	0.003	13343.367	Fixed,Phase Diff
Base2	S06	4/23/2012 10:49:44 AM	00:01:00	-13221.226	-2181.640	-31.064	0.002	0.003	13399.271	Fixed,Phase Diff
Base2	1	4/23/2012 11:20:56 AM	00:00:01	-13492.965	-2111.000	-48.317	0.017	0.023	13656.371	Fixed,Phase Diff
Base2	4	4/23/2012 11:21:11 AM	00:00:01	-13495.527	-2103.152	-48.321	0.015	0.020	13657.691	Fixed,Phase Diff
Base2	121	4/23/2012 11:28:07 AM	00:00:01	-13953.110	-2285.327	-48.307	0.015	0.020	14138.259	Fixed,Phase Diff
Base2	192	4/23/2012 11:34:47 AM	00:00:01	-14438.212	-2417.452	-48.283	0.016	0.022	14638.394	Fixed,Phase Diff
Base2	291	4/23/2012 11:43:19 AM	00:00:01	-14954.450	-2458.382	-48.270	0.015	0.021	15154.330	Fixed,Phase Diff
Base2	399	4/23/2012 11:49:53 AM	00:00:01	-15271.106	-2058.418	-48.240	0.016	0.024	15408.342	Fixed,Phase Diff
Base2	465	4/23/2012 11:55:59 AM	00:00:01	-15466.939	-1635.629	-48.245	0.016	0.025	15552.296	Fixed,Phase Diff
Base2	585	4/23/2012 12:02:58 PM	00:00:01	-15716.099	-1202.987	-48.206	0.015	0.022	15761.161	Fixed,Phase Diff
Base3	1272	4/23/2012 12:32:38 PM	00:00:01	-101.591	-112.640	1.239	0.020	0.022	151.678	Fixed,Phase Diff

Fig.4 Real time GNSS solutions using ROMPOS RTK.

Were measured about 102000 points that are known with high precision the geodetic coordinates: latitude, longitude and altitude in ETRS89 reference ellipsoidal system. Position of the determined profiles is shown in the following figure:

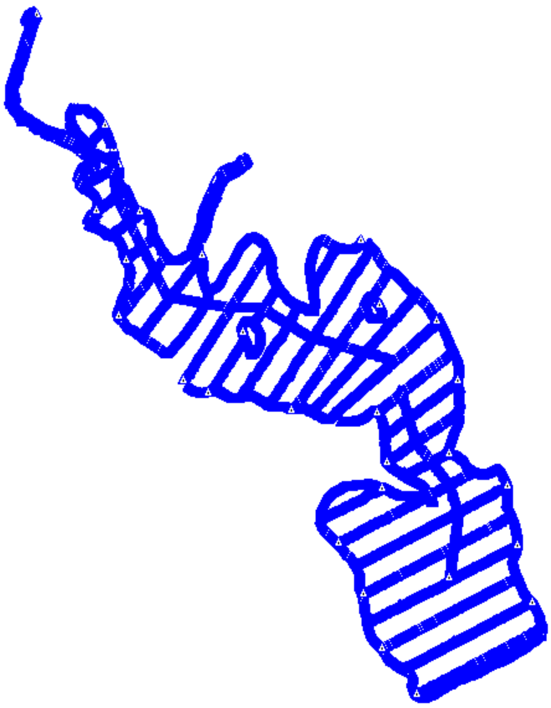
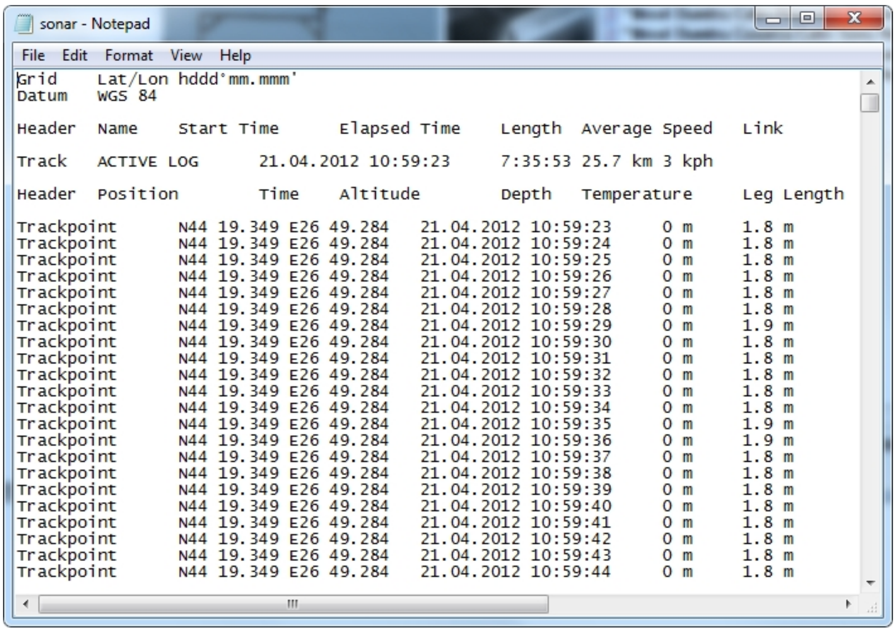


Fig.5 Points position on profiles.

The method involves the development of sonar depth measurements while achieving GNSS measurements. In this sense, depth taken were recorded and stored on the memory card of the Garmin GPSMAP 421s sonar that has been downloaded after that at the office.

The format of a file containing depth measurements is shown in the following figure. Besides information on the depth, sounder records the approximate positions of the points, the time at which the measurement was performed and speed. For optimal solutions for both depth measurements and for real time GNSS technology the designed and developed speed was approximately 3 km/h.



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sonar - Notepad
File Edit Format View Help
Grid      Lat/Lon hddd°mm.mmm'
Datum     WGS 84

Header    Name      Start Time       Elapsed Time    Length   Average Speed    Link

Track     ACTIVE LOG     21.04.2012 10:59:23     7:35:53 25.7 km 3 kph

Header    Position         Time      Altitude         Depth    Temperature      Leg Length

Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:23    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:24    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:25    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:26    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:27    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:28    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:29    0 m    1.9 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:30    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:31    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:32    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:33    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:34    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:35    0 m    1.9 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:36    0 m    1.9 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:37    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:38    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:39    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:40    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:41    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:42    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:43    0 m    1.8 m
Trackpoint      N44 19.349 E26 49.284    21.04.2012 10:59:44    0 m    1.8 m
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Fig. 6 Format of the sounder recorded file.

A quick view of the depths can be achieved with specialized software. A quick view in the field (Fig. 7) is a solution to check the determinations given that the depths in an intersection of two profiles (longitudinal to transverse) should be approximately the same. If this does not check those profiles are going to be recovered.

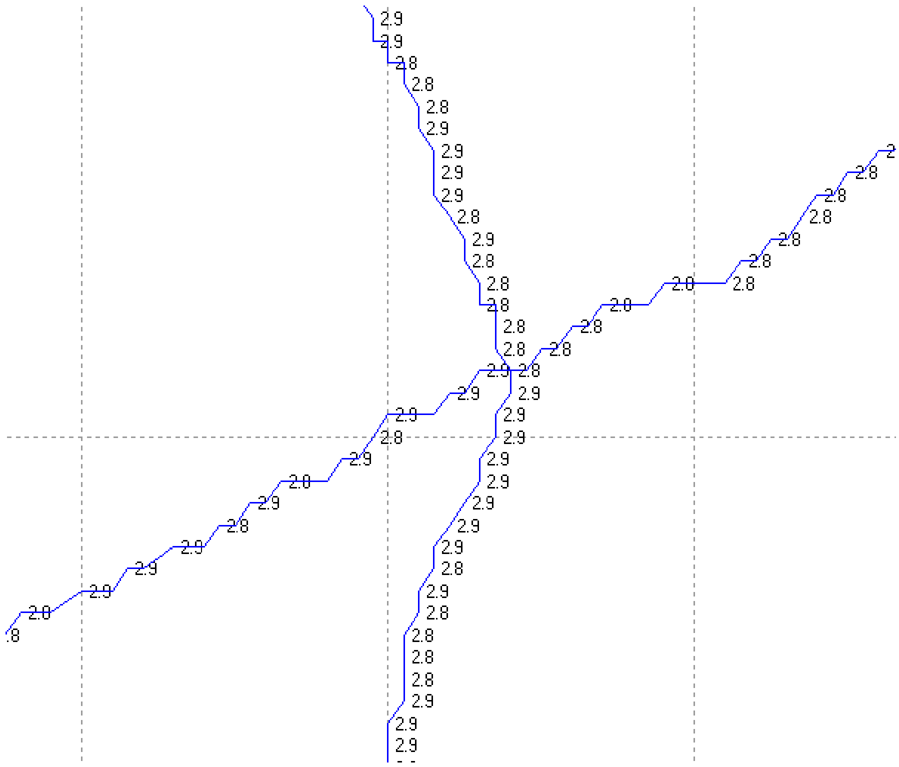

Fig.7 Depths of the transversal profile crossing the longitudinal profile.

An important phase of the bathymetric works is to determine the coordinates of the bottom of the lake. In this respect, measurements results of the two equipment will be concatenated following that the planimetric positions represented by the ellipsoidal geodetic latitude and longitude to be taken from the real-time GNSS/ RTK and the altitude to be calculated by the difference between the ellipsoidal altitude determined by GNSS equipment and the depth acquired by sonar . Concatenation will be using as the "primary key" the time of the two measurements. For this was made an application that automatically identifies times above, take geodetic coordinates from the source file of coordinates determined GNSS, makes the difference between ellipsoidal altitude and depth and altitude, the results being presented as an inventory containing coordinate positions of the bottom of the lake for the measured profiles . The inventory contains coordinates in the ETRS89 reference system. Coordinate transformation in the national reference system S-42 Stereographical projection 1970 it is made using the TransDatRo application, the official application for coordinate transformations implemented for all national territory. To determine altitude in the national reference system with zero fundamental point Black Sea 1975 it was used the interpolation in a local quasigeoid grid modelled for the area of interest [1]. The anomalies of the altitudes were interpolated based on ellipsoidal coordinates and then it will be obtained the normal altitude by the difference between ellipsoidal altitude and anomaly of the altitude.

Besides bathymetric measurements, there were made determinations of the ridge of the lake by GNSS/RTK technique. They were used along with the bathymetry of the lake to achieve the 3D model in this case (Fig. 8). The 3D model was generated using an application developed using Matlab allowing the visualisation of the generated model but also permit the interpolation and volume calculations [2], [4]. The 3D model created can be integrated into any Digital Terrain Model developed by airborne techniques.

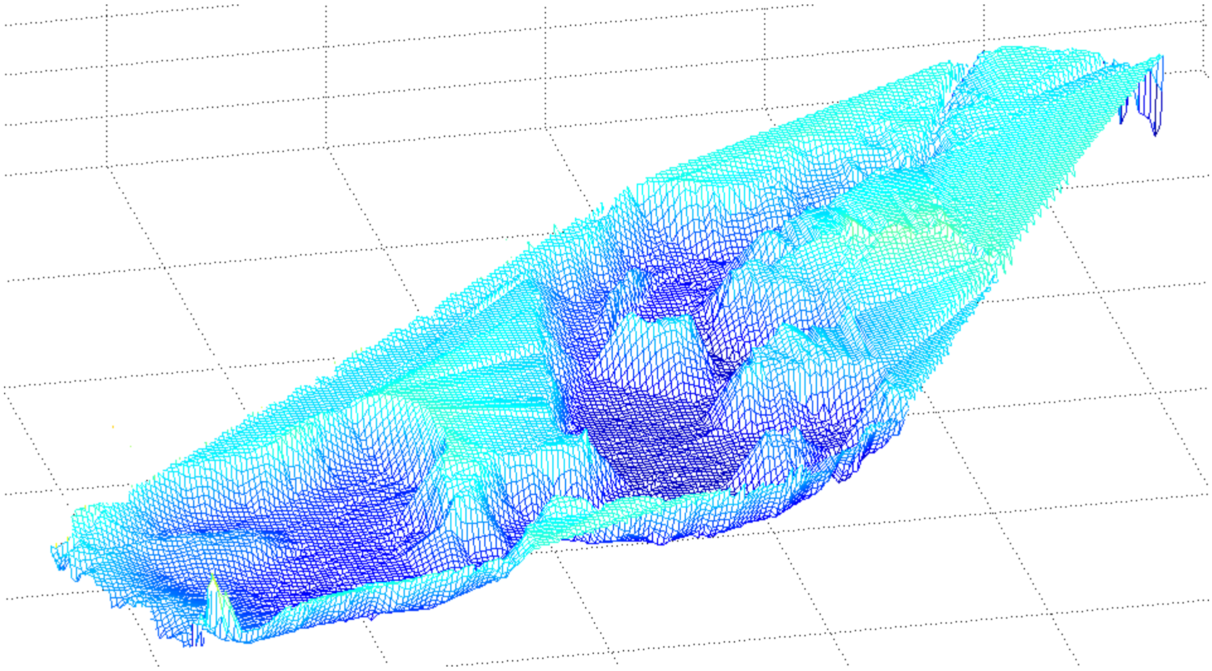

Fig.8 3D representation of the lake.

4. Conclusions

The equipment complies with the standards for hydrographical measurements. The works were carried out in order to meet both personnel safety and measurement accuracy required to correct measure cross sections transversal / longitudinal, contour of the lakes in the normal retention rate at canopy level.

In order to integrate measurements and final coordinates in the national reference name in rigor required by regulations issued by ANCPI were achieved by GNSS technology a bridging network. It was made a bridging network consisting of 4 points. Determinations were performed by static GNSS method. To determine the coordinates in ETRS89 system was used measurements from GNSS permanent stations that are part of the national network (BUCU, COST, etc) and the adjustments were performed by constraining the coordinates of these permanent stations.

The bridging network was used for checking the GNSS/RTK (real time) determinations. It was real time measured the points of the bridging network caused by static methods. Differences between RTK and static determinations fit in the tolerances specified in the regulations.

Bathymetric measurements were performed by GNSS technology , the kinematic/RTK method of measuring, using dual frequency receivers L1, L2, GPS/GLONASS and using RTK differential corrections from the positioning system ROMPOS. Also, the kinematic GNSS measurements can be performed in real time using a base-rover distributing differential corrections to an UHF radio modem. In this case, depending on the size of the lake can be moved to other points in the network of thickening where the radio signal is not strong enough. However, the use of the base-rover system would increase the productivity where ROMPOS positioning system is unavailable due to the lack of GSM / GPRS signal in the working area.

There were measured longitudinal and cross sections (transversal) profiles that were designed in advance, the ridge of the lake and the normal retention contour and profiles downstream of the dam.

Bathymetry works involve a high degree of complexity by using multiple technologies for measurements. The method that combined sounder with GNSS equipment achieves faster and superior results.

5. *References*

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