GEODESY AND CARTOGRAPHY

ISSN 2029-6991 / eISSN 2029-7009

2016 VOLUME 42(3): 136–139

https://doi.org/10.3846/20296991.2016.1226395

UDK 528.385

DEVELOPMENT OF LATVIAN NATIONAL 2ND ORDER LEVELING NETWORK

Madara ZNOTINA, Ivars LIEPINS, Ksenija KOSENKO

Latvian Geospatial Information agency, Ojara Vaciesa str. 43,
LV-1004 Riga, Latvia
E-mail: info@lgia.gov.lv (corresponding author)

Received 09 November 2015; accepted 30 November 2016

Abstract. Latvian National First Order Levelling Network consist of 15 polygons and 51 lines and was re-established in 2011. From 1st of December of year 2014 in Latvia Republic is new Latvian normal height system at epoch 2000,5. Normal heights are widely used in origination and application of geospatial data in civil engineering and quasigeoid computation etc. The main objective of this work is to describe 2nd order leveling network development idea, purpose and process. Essential of work is option, check, used and analyze historical height data, which has all Eastern European countries, and newly measured height data.

Keywords: vertical network, leveling, State 2nd order leveling network.

Introduction

Latvian National First Order Levelling Network (LNFOLN) field work continued from year 2000 until 2010. Geodetic measurements were made by the specialists of the Latvian Land Service from 2000 until 2005 and Latvian Geospatial Information agency from 2006 until 2010. Establishment and measurements were done following the technical requirements of an “I, II and III classes levelling instruction” (Latvian Land Service 2000). Some extra checking was done in 2011 to verify suspicious places.

Connections with Lithuanian National First Order Levelling Network was done from 2007 until 2010, common pre-adjustment of two country first order-levelling networks was done in 2011 (Aleksejenko *et al.* 2011). Connection with Estonian National First Order Levelling Network was done in year 2008 and 2011 in four historical levelling network places.

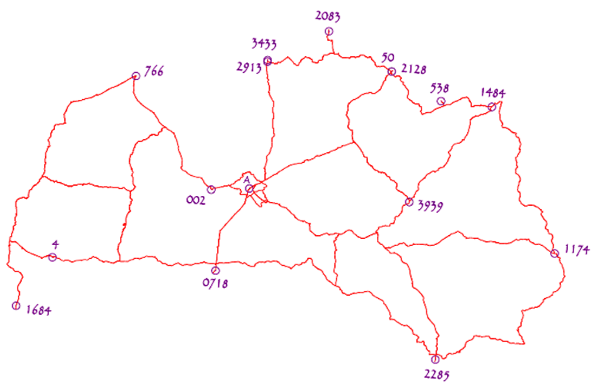

Fig. 1. 16 stabile benchmarks of EVRS realization in Latvia

Obtaining, submission, adjustment and acquisition of geopotential numbers of specially choose LNFOLN in European Vertical reference system (EVRS) done using recommendation of Reference Frame Sub commission for Europe (Sacher *et al.* 2008).

Latvian normal heights system is based on 16 stable benchmarks which are choose all over the country (see Fig. 1) and geopotential values are reduce to epoch 2000,5. Adjustment of LNFOLN done during year 2011 until 2012. At 1st of December of year 2014 EVRS realization for Latvia by name of Latvian normal height system at epoch 2000,5 become official height system at mainland of Latvia.

LNFOLN consists of 15 polygons (5 of them specially made for capital city Riga) and 51 lines. Amount and density of Latvian National Levelling Network must be densify for purposes of local municipality’s networks, improvement of quasigeoid model and civil engineering needs. That are reasons why 1st order leveling network densification by means of 2nd order leveling network must be done.

Latvian national 2nd order leveling network developing process is ongoing with combination of historical and newly measured leveling data. Development of Latvian national second order leveling network starting year 2012 at Latvia's southeastern region (Latgale), in year 2013 at Latvia's northeastern region (Vidzeme), in year 2014 Latvia's south region (Zemgale) and in year 2015 in Latvia's west region (Kurzeme). Final measurements and adjustment is plan to be in year 2016.

1. Main part

Territory of the Republic of Latvia was covered completely our partly three time in last 90 years by levelling networks:

- First from year 1929 until 1939 by Latvian Agriculture ministry specialists covered all country with 1st levelling network. Catalogue printed in Soviet occupation as V. Salnajs "Latvian SSR precise leveling" catalogue 1929–1939 ("Latvijas PSR precīzā nivelēšana") (Salnajs 1940);
- Secondly, USSR Main Administration of Geodesy and Cartography made 1st order levelling without closed polygons in Latvia territory. 2nd, 3rd and 4th levelling networks completely covered Latvia. Mostly in 2nd order network used previously made levelling data from Latvian SSR precise leveling. Height data were publicized in series of catalogues (the publisher "Главное управление геодезии и картографии при совете министров СССР") (1922–1989).
- Thirdly, from year 2000 until 2010 LNFOLN was measured, adjusted and finalized in Latvian Geospatial Information Agency report 1st order levelling network of Republic of Latvia (Latvian Geospatial Information Agency 2013).

Further development of Latvian National Levelling network, maintenance of height system and interest of national economy pushed forward idea of 2nd order levelling network. Precisely levelled height data coverage of Latvia must be as evenly as possible and finalization of 2nd order levelling must be done as fast as possible. Establishment and measurements of newly 2nd order network is using the technical requirements of an "I, II and III class levelling instruction (Latvian Land Service 2000).

Territory of Latvia have historical measurements with full our partly metadata about them that could be used to minimize field works and maximize benefit of already option data.

Result of research and adjustment is calculate normal heights for Latvian national 2nd order leveling network using combined historical and newly measured leveling data.

Objects of research:

I. Investigation of data and metadata of historical levelling data;
II. Equalize historical data to common epoch 2000,5, if necessary make reduction to normal heights;
III. Control of historical data:
   a. Cameral with adjustment into LNFOLN;
   b. Field measurements on preserved benchmarks;
IV. Common newly option and historical data adjustment. Comparing with levelling network accuracy limits.

In some places not for purpose of checking, it is necessary to supplement historical data with leveling field works to fully complement 2nd order leveling network:

- to join 1st order leveling benchmarks with 2nd order leveling benchmarks;
- to join 2nd order global positioning points with 1st or 2nd order leveling network;
- newly made leveling lines;
- to determine Latvian permanent GNSS positioning base station system (LatPos) base stations with normal heights.

Field measurements is done with digital levels Trimble DiNi 12 and Trimble DiNi 0.3 in complete with invar bar code scales rods. Leveling set is calibrate once every year at Finnish Geodetic Institute before field session. All leveling lines divide into sections. Every section leveled forwards and backwards using alternative method aFBBF. Distance between benchmarks in newly established lines is approximately 2–4 km. In historical data as it is, but not longer than 2 km in urban area and 7 km in rural area.

Investigation of historical data show up that accuracy of properly selected data is of high level, but there is areas and lines that are low accuracy and cannot use for common adjustment. That is reason why very deep and rigorous analyze of historical data must be done.

Before common data processing, historical and newly obtained leveling data must have several corrections for transaction to normal elevations and normal height calculation.

As common in geodesy, newly measured elevation must be correct by:

- rod scale factor (tested before each field session in Finnish Geodetic Institute for levelling complete);

- thermal expansion coefficient (tested before each field session in Finnish Geodetic Institute for levelling complete);
- temperature during levelling complete calibration;
- temperature during leveling field works.

Correction is calculate by formula:

$$L = h\left(m_0 + \alpha\left(T - T_e\right)\right),$$

where: h – measured mean elevation forward and backward direction; m_0 – rod scale factor; α – thermal expansion coefficient; T – temperature during levelling field works; T_e – temperature during calibration.

All 2[nd] order leveling network is measured in different periods of time during beginning and middle of 20[th] century and beginning of 21[st] century. Before adjustment, elevation data must be in one common epoch. Reduction to common Latvian normal height system 2000,5 is done to all elevation data.

From historical catalogues of USSR Main Administration of Geodesy and Cartography exact time of measurements usually can be found. If not approximation of middle, levelling time is used. Latvian Geospatial information agency (LGIA) formed empirical Latvia Earth's crust vertical movement model for reduction to common epoch (see Fig. 2). Input data in model are height differences and height data of LNFOLN points from V. Salnajs "Latvian SSR precise leveling" catalogue (Salnajs 1940) and newly obtain data from 2000 until 2010 levelling. Latvia Earth's crust vertical movement model representation as Earth's crust vertical movement velocity isolines (values 1 mm/y, 0.5 mm/y, 0 mm/y, –0.5 mm/y and –1 mm/y) are utilized in interpolation method. Also surface of Latvia Earth's crustal model is made in Surfer program by Golden Software kriging interpolation. For each newly measured line and historical nodal point, the velocity of Latvia Earth's crust vertical movement was calculated and a reduction of the measured elevation to the common epoch was calculated via formula:

$$\delta = \left(t_{ep} - t_m\right)\left(v_{end} - v_{start}\right),$$

where t_{ep} – common reduction epoch 2000.5; t_m – epoch of measurements year; v_{end} – velocity of Latvia Earth's crust vertical movement model at leveling line end point; v_{start} – velocity of Latvia Earth's crust vertical movement model at leveling line start point.

Normal elevation between points calculate by theoretical gravity value is calculated via formula:

$$\gamma_0 = 9.780327\left(1 + 0.0052024 \cdot \sin^2\beta - 0.0000058 \cdot \sin^2\beta\right),$$

where β – geodetic latitude in radians.

Leveling network adjustment performed by software *Nivelier 1.1* (Нивелир 1.1). Software *Nivelier 1.1* is Belarus company Credo-Dialogue product. Checking is done by Latvian program of lest-square 1[st] order levelling adjustment in TopoNet package. Results from both programs are nearly the same. Required data for leveling network adjustment are:

- national point ID or unique code;
- distance between points;
- normal elevation;
- given point heights (in European Vertical reference system realization EVRF2007 re-adjustment with new Latvia data).

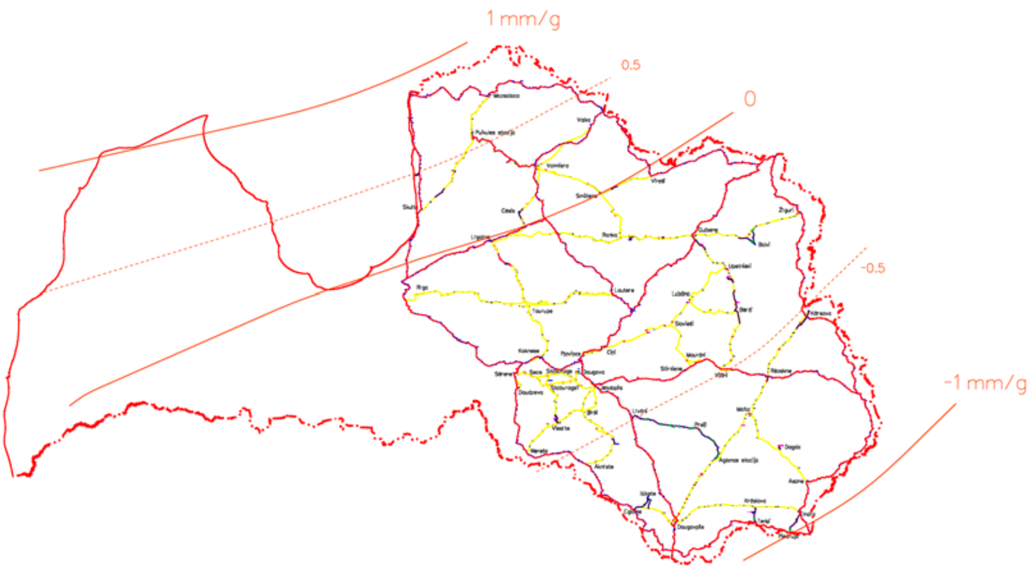

Fig. 2. LGIA formed Latvia Earth's crust vertical movement model and adjusted part of 2[nd] order network fig

Before adjustment newly measured and historical lines are connected in systems with common nodal points and fixed points on 1^{st} order leveling lines. In Latvian national 2^{nd} order leveling network in Latgale and Vidzeme regions are included 539 points of whom 39 are given Latvian national 1^{st} order leveling network points. At this moment in Zemgale area are included 82 points of whom 9 are given Latvian national 1^{st} order leveling network points. In Zemgale area still continue leveling works.

Accuracy estimation is done to all system. In Latgale area all systems accuracy is 1.8 mm/km. In Vidzeme area all system accuracy is 1.9 mm/km. In Zemgale area part of system accuracy is 1.6 mm/km.

Conclusions

Historical and newly obtain high accuracy levelling data can be used for establishment of national 2^{nd} order network in Latvia area.

Combination algorithm of historical and newly obtain data is developed, attested and used in Latvia.

Both data sets historical and newly are processed step by step:
- historical data acquisition;
- verification of historical data;
- newly measured data obtaining;
- correction and reduction of data to common epoch and normal height system;
- data combination in system and adjustment of systems;
- analyses of data and elimination of outliers.

Using of historical data after verification diminish leveling field works and increase speed of densification of 2^{nd} order network.

In area with impact of land uplift phenomena special model need to be used to get height differences to common epoch.

Newly and historical benchmarks density is very important for national leveling network and survey from them. Distance between newly benchmarks is approximately 3 km. Distance between historical benchmarks can be no longer than 2 km in urban area and 7 km in rural area to use historical data in leveling. Special attention and some extra field works must be done to control this distance.

Each newly established line should satisfy requirement $4\text{ mm}\sqrt{L}$ to use data in further calculations.

Standard deviation of Latvian national 2nd order leveling network in Latgale, Vidzeme and Zemgale regions is 1.8 mm/km.

References

Aleksejenko, I.; Kaminskis, J.; Sakne, J., *et al.* 2011. Levelling network connection between Latvian and Lithuania, in *The 8th International Conference "Environmental Engineering"*: selected papers, 19–20 May 2011, Vilnius, Lithuania, 1269–1277. ISNN 2029-7106.

Latvian Geospatial Information Agency. 2013. *Latvian 1st order leveling review*. Latvia (in Latvian).

Latvian Land Service. 2000. *I, II and III classes levelling instruction*. Latvia (in Latvian).

Sacher, M.; Ihde, J.; Liebsch, G.; Mäkinen, J. 2008. EVRF07 as realization of the European vertical reference system, presented at the Symposium of the IAG Sub-commission for Europe (EUREF) in June 18–21, 2008, Brussels, *Bollettino di Geodesia e Scienze Affini* 68(1): 35–50.

Salnajs, V. 1940. *Latvian SSR precise leveling*. Riga, Latvia (in Latvian and Russian).

Madara ZNOTINA works as Expert of Division of Geodesy at Latvian Geospatial Information Agency. She holds MSc Ing. in Geomatics from Riga Technical University, Latvia. Her research interests are heights systems and Struve Geodetic Arc.

Ivars LIEPINS is a PhD student at Riga Technical University, Latvia and currently works as Head of Division of Geodesy at Latvian Geospatial Information Agency. His research interests are heights systems, quazigeoid models and gravimetry.

Ksenija KOSENKO currently serves as Head of Geodetic measurements sector of Division of Geodesy at Latvian Geospatial Information Agency. She holds MSc Ing. in Geomatics from Riga Technical University, Latvia. Her research interests and responsibilities are global positioning, coordinate and height reference systems.