PRECISION OF LATVIA LEVELING NETWORK NODAL POINT HEIGHT

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ABSTRACT

This study provides an assessment of the accuracy of performed first order leveling at the period from 2000 to 2010. For the newly created leveling network, the standard deviation of each leveling network nodal point, in relation to the starting points, chosen in different parts of the country, is defined. Furthest from the century benchmark fr002 the fundamental benchmark 1174 is located in Zilupe, which heights standard deviation is 9,7 mm and the fundamental benchmark 1463 in Jurkalne, which height standard deviation is 8,2 mm. The obtained accuracy value influencing factors are discussed and recommendations for further research are provided. In general, the performed leveling provides the opportunity to use the estimated height values for the existing height system actualization and successful inclusion in the European Vertical Reference System.

Key words: nodal points, leveling network, standard deviation

INTRODUCTION

First order leveling network is a decisive factor for development of the national height system. Therefore, leveling must be carried out with the highest possible accuracy.

This research deals with Latvia I class leveling network nodal points accuracy. For this research The Latvian Geospatial Information Agency data about performed leveling from 2000 to 2010 were used.

The aim of the research is to provide accuracy assessment of the most topical leveling data. The standard deviation of each leveling network nodal point, in relation to the starting points, chosen in different parts of the country, is defined.

This type estimation of the leveling network accuracy so far has not been done.

MATERIALS AND METHODS

National leveling core network is the height system developer and maintainer of a given territory. The established leveling core network accuracy gives guarantees for other studies that the data from this network are of high quality. As an example, studies on the Earth crust vertical movements, their speed and amplitude of values. To accurately determine the exact changes that occurred, the leveling must be executed with the best possible accuracy (Ellmann et al., 1999). In case, if precise leveling final results for some reason are not with the highest certainty, then it is very difficult for further data application in the national economy (Celms et al., 2012).

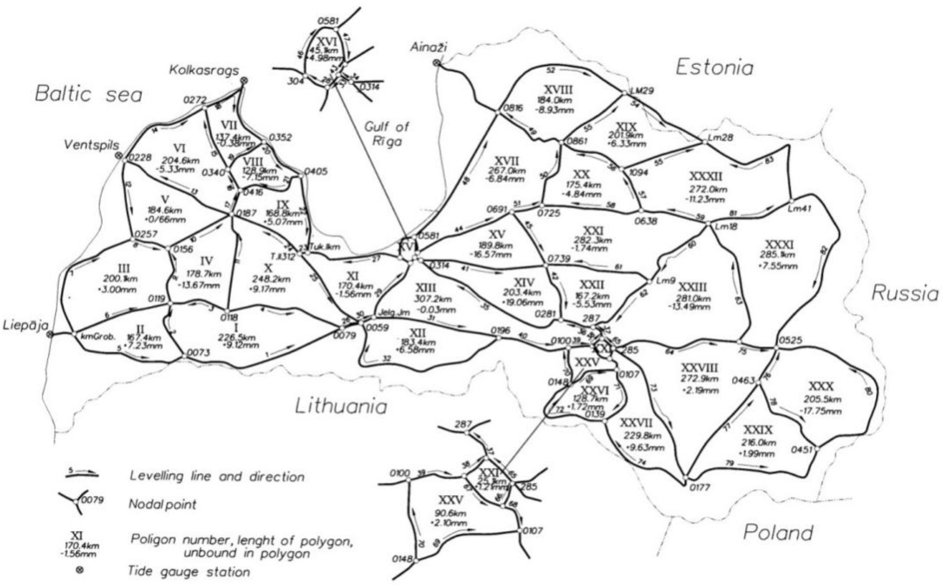

Figure 1. Scheme of 1929–1939 leveling network

In the territory of Latvia during the last seventy years three precise leveling campaigns were performed. In the territory of Latvia the core leveling network was created from 1929 to 1939 (Fig.1). During this period in the territory of Latvia the overall first order leveling network was set and surveyed. The leveling network reached the total length of 4422 km and included 1262 leveling signs (Latvijas PSR …, 1941). The leveling network was unsystematic, re-leveled in the last century two more campaigns – at the time from 1947 to 1948 (Fig.2). During this period leveling was performed by separate existing core network leveling lines. It was done in order to include the leveling core network in the Soviet Union geodetic space.

During the period from 1967 to 1974 precise leveling was carried out again (Fig.3). Almost all lines were leveled again. In the leveling lines, where measurements were not fulfilled, the elevation values between the unit points were taken from the previous (1929 – 1939) epoch measurement data.

Fragmentarily precise leveling was organized and carried out until 1990.

The most recent first order leveling in Latvia was performed during the period from 2000 to 2010 (Fig.4). At the time period from 2000 to 2005 precise leveling works were organized and performed by the State Land Service. In the following period – from 2006 to 2010 these works were continued and successfully completed by the Latvian Geospatial Information Agency experts. Leveling was performed by the existing lines, including in previous campaigns leveled leveling signs, which were preserved till the present day. In this epoch, separate lines in some sections were leveled by new sites (Instruction of …, 2001). As an example, in the line Zilupe – Demene leveling in the section Indra – Demene was prepared and fulfilled not by the previous epoch measured lines. It was related to the Latvian border geodetic surveying grounds preparation.

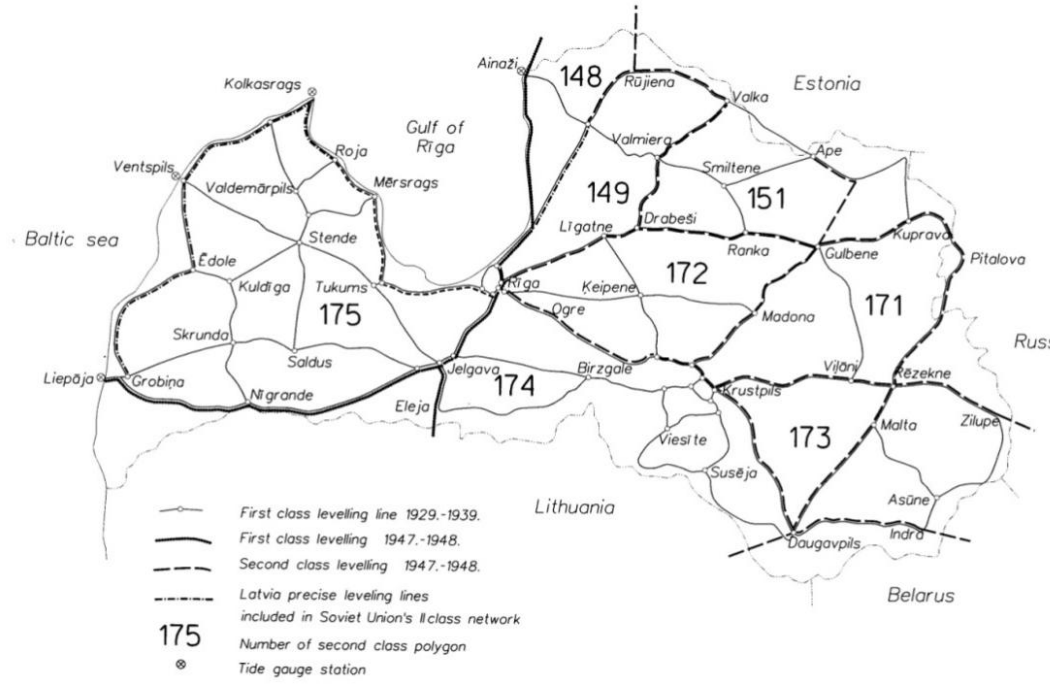

Figure 2. Scheme of precise leveling network from 1947 to 1948

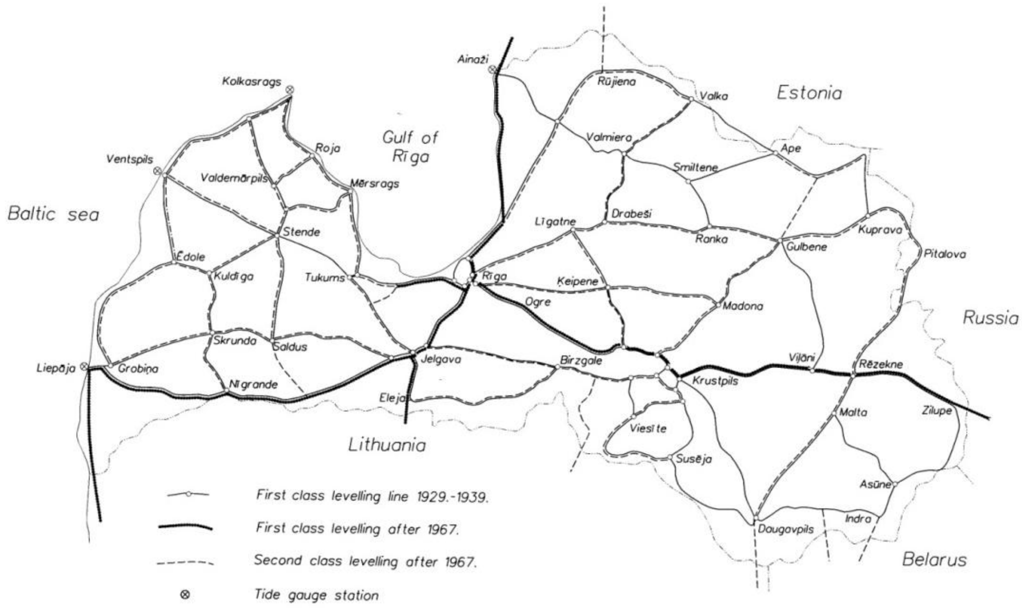

Figure 3. Scheme of precise leveling network from 1967 to 1974

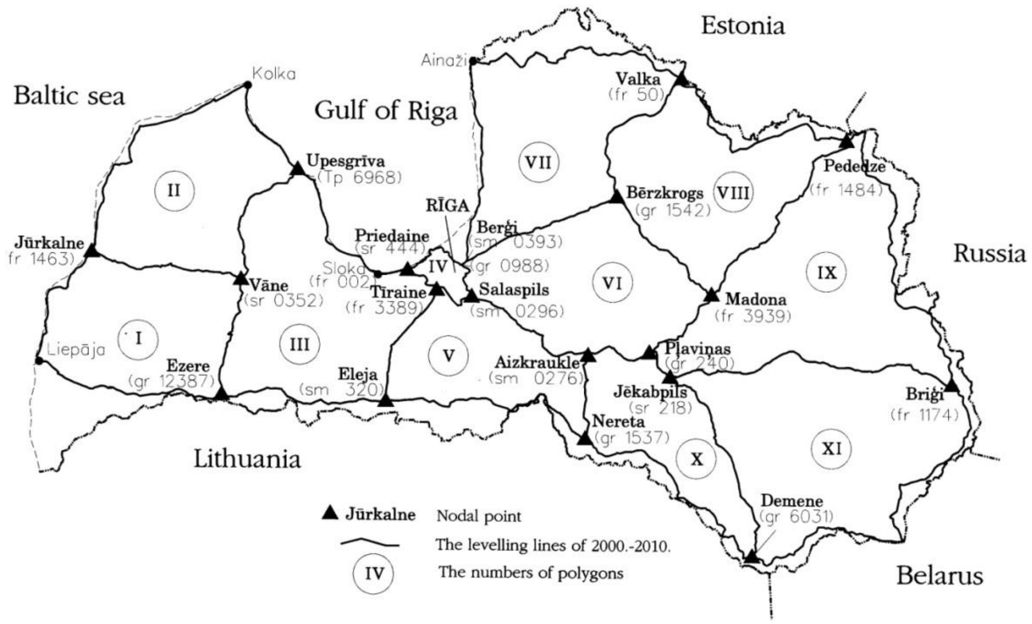

Figure 4. Scheme of first order leveling network

Only for the 1929–1939 leveling, the farthest placed nodal point standard deviation, in relation to the central part of the leveling network, has been calculated (wall mark Sm304 in Zasulauks) (Jakubovskis et al., 1994). These calculations were performed only in 1992, because in the 30's it took massive additional calculations, which were not performed. In total, there were 51 nodal point height standard deviations determined to the wall mark Sm304 in Zasulauks (Table 1). Standard deviation in the west direction (280 km) is less than 5 mm and east direction (350 km) – less than 6 mm. The estimated standard deviations of the nodal points are shown in Table 1. The obtained results show that, despite the technical possibilities of that time and experience, leveling works were performed with the highest accuracy.

Table 1
Nodal points height standard deviations in relation to wall mark Sm304 in Zasulauks

Nodal point	Height mean square error, mm	Line Nr.
0079	±3,9	1,4,26
0073	±5,3	1,2,5
0119	±5,0	2,3,4,9
00118	±4,8	3,4,11
Grobiņa	±5,7	5,6,7
0257	±5,3	7,8,12
0156	±5,1	8,9,10
0187	±4,5	10,11,13,17,24
0228	±5,4	12,13,14
0272	±5,5	14,15,18
0340	±5,1	15,16,19
0416	±4,8	16,17,21
0352	±5,3	18,19,20
0405	±4,9	20,21,22
Tukums I	±3,8	22,23,27
312	±3,8	23,24,25
0059	±3,4	25,26,30,32
303	±1,1	28,29,33
Jelgava	±3,3	29,30,31
0196	±4,3	31,32,40
0254	±1,6	33,34,43
0314	±1,9	34,35,41
0281	±3,8	35,36,42
287	±4,0	36,37,62
0168	±4,1	37,38,65
0102	±4,2	39,39,47
0100	±1,3	39,40,70
0739	±3,7	41,42,45,61
0346	±1,8	43,44,47
0691	±3,7	44,45,51
0581	±2,1	46,47,48
0816	±4,6	48,19,52
0861	±4,4	49,50,53,56
0725	±4,0	50,51,58
29	±5,1	52,53,54
28	±5,2	54,55,93
1094	±4,7	55,56,57
0638	±1,3	57,58,59
18	±4,6	59,60,63,81
9	±4,4	60,61,62
22	±5,1	63,64,75
285	±4,2	64,65,66,73
0106	±4,2	66,67,68
0107	±4,7	68,69,71
0148	±4,7	69,70,72
0139	±5,3	71,72,74
0177	±5,4	73,74,77,79
0525	±5,2	75,76,80,82
0463	±5,5	76,77,78
0451	±6,0	78,79,80
41	±5,2	81,82,83

In this study, the most recent leveling network data were used. The raw data were obtained from the Latvian Geospatial Information Agency. These data were arranged by lines; in the result from these lines polygons were created. For each line the leveling data were arranged in a specific sequence showing the leveling signs, elevation between them and the distance between the leveling signs. The elevation values between the leveling signs are given as average, taking into account the "forward" and "back" measurements. The elevation values are given with the calibration corrections and including coefficients for the transition to the normal height system (Instruction of …., 2001).

To achieve the objectives stated in this study the Latvian class I leveling network equation by the parametric method was carried out (Gaidaev et al., 1969). In calculations by this method, for measurement results elevations, measured between the nodes are taken, but for the parameters (unknown) – node adjusted heights. Then the numbers of the parametric equations are equal to the numbers of the leveling network lines n, but the numbers of the parameters are equal to the leveling network nodes t.

Defining the node Mj adjusted height $H_j = (H_j) + \xi_j$, where (H_j) is the node height approximate value, but $\xi_j$is correction to j = 1, 2, ….., t (Table 2), parametric equations in following form are obtained:

$$a_i \xi_1 + b_i\xi_2 + \dots + t_i\xi_t - \lambda_i = v_i$$

$$i = 1, 2, \dots , n \qquad (1)$$

where:
n – number of lines
v – elevation correction
λ – mathematical difference between the measured elevation value and leveling network node height approximate values

$$\lambda_i = l_i - (h_i) \text{ with weight } p_i \qquad (2)$$

where:
l_i – measured elevation of leveling line
(h_i) – height approximate value (Table 3)

Using the Gauss lemmas equations [av]=0; [bv]=0; … [tv]=0, following the correction parametric equations, a normal equation system is drawn up (Fig. 5).

Table 2

Leveling network point heights

H_{444}	=	2,9700			
H_j		(H_j)		ξ_j	
H_1	=	12,6510	+	$\xi 1$	Tp6968
H_2	=	13,4018	+	ξ_2	Fr1463
H_3	=	87,5046	+	ξ_3	Sr0352
H_4	=	72,7757	+	ξ_4	Gr12387
H_5	=	33,5612	+	ξ_5	Sm320
H_6	=	12,3026	+	ξ_6	Fr3389
H_7	=	13,3314	+	ξ_7	Gr0988
H_8	=	10,4439	+	ξ_8	Sm0393
H_9	=	17,8528	+	ξ_9	Sm0296
H_{10}	=	80,2234	+	ξ_{10}	Gr1537
H_{11}	=	95,2382	+	ξ_{11}	Sm0276
H_{12}	=	179,1619	+	ξ_{12}	Gr1542
H_{13}	=	49,6972	+	ξ_{13}	Fr50
H_{14}	=	84,5788	+	ξ_{14}	Gr240
H_{15}	=	141,1518	+	ξ_{15}	Fr3939
H_{16}	=	156,6380	+	ξ_{16}	Fr1484
H_{17}	=	132,1347	+	ξ_{17}	Gr6031
H_{18}	=	91,3675	+	ξ_{18}	Sr218
H_{19}	=	130,3630	+	ξ_{19}	Fr1174

The normal equation system is derived using the Gauss algorithm (Freijs, 1957). As a result ξ adjusted values are obtained, by which the leveling network node adjusted heights are calculated.

For the performed calculations as a starting point of the height system the leveling sign sr444 was taken. It was set because that the wall benchmark sr444 is located 10 km away from the wall mark sm304. Therefore, the obtained results can be comparable to the 1929 - 1939 leveling standard deviation of the leveling network node points.

The height standard derivation is calculated for XIX nodal point, which naturally is embedded as a fundamental ground mark fr1174.

Table 3

Correction parametric equations

																							weight (p)
H_{II}	-	H_I	-	h_1	=	v_1	13,4018	-	12,6510	-	0,7561	=	-5,3		-	$\xi 1$	+	$\xi 2$	+	-5,3	=	v_1	0,0049
H_{II}	-	H_{III}	-	h_2	=	v_2	13,4018	-	87,5046	-	-74,0977	=	-5,1			ξ_2	-	ξ_3	+	-5,1	=	v_2	0,0117
H_{III}	-	H_I	-	h_3	=	v_3	87,5046	-	12,6510	-	74,8532	=	0,4		-	$\xi 1$	+	$\xi 3$	+	0,4	=	v_3	0,0122
H_{IV}	-	H_{II}	-	h_4	=	v_4	72,7757	-	13,4018	-	59,3844	=	-10,5		-	$\xi 2$	+	$\xi 4$	+	-10,5	=	v_4	0,0054
H_{IV}	-	H_{III}	-	h_5	=	v_5	72,7757	-	87,5046	-	-14,7289	=	0,0		-	$\xi 3$	+	$\xi 4$	+	0,0	=	v_5	0,0138
H_V	-	H_{IV}	-	h_6	=	v_6	33,5612	-	72,7757	-	-39,2228	=	8,3		-	$\xi 4$	+	$\xi 5$	+	8,3	=	v_6	0,0110
H_V	-	H_{VI}	-	h_7	=	v_7	33,5612	-	12,3026	-	21,2669	=	-8,3			ξ_5	-	ξ_6	+	-8,3	=	v_7	0,0144
H_{444}	-	H_{VI}	-	h_8	=	v_8	2,9700	-	12,3026	-	-9,3326	=	0,0				-	ξ_6	+	0,0	=	v_8	0,0409
H_I	-	H_{444}	-	h_9	=	v_9	12,6510	-	2,9700	-	9,6814	=	-0,4					ξ_1	+	-0,4	=	v_9	0,0108
H_{VII}	-	H_{444}	-	h_{10}	=	v_{10}	13,3314	-	2,9700	-	10,3614	=	0,0					ξ_7	+	0,0	=	v_{10}	0,0233
H_{VII}	-	H_{VIII}	-	h_{11}	=	v_{11}	13,3314	-	10,4439	-	2,8875	=	0,0			ξ_7	-	ξ_8	+	0,0	=	v_{11}	0,3472
H_{VI}	-	H_{IX}	-	h_{12}	=	v_{12}	12,3026	-	17,8528	-	-5,5447	=	-5,5			ξ_6	-	ξ_9	+	-5,5	=	v_{12}	0,0374
H_{IX}	-	H_{VII}	-	h_{13}	=	v_{13}	17,8528	-	13,3314	-	4,5268	=	-5,4		-	$\xi 7$	+	$\xi 9$	+	-5,4	=	v_{13}	0,0400
H_X	-	H_V	-	h_{14}	=	v_{14}	80,2234	-	33,5612	-	46,6622	=	0,0		-	$\xi 5$	+	$\xi 10$	+	0,0	=	v_{14}	0,0079
H_X	-	H_{XI}	-	h_{15}	=	v_{15}	80,2234	-	95,2382	-	-15,0159	=	1,1			ξ_{10}	-	ξ_{11}	+	1,1	=	v_{15}	0,0199
H_{IX}	-	H_{XI}	-	h_{16}	=	v_{16}	17,8528	-	95,2382	-	-77,3842	=	-1,2			ξ_9	-	ξ_{11}	+	-1,2	=	v_{16}	0,0125
H_{VIII}	-	H_{XII}	-	h_{17}	=	v_{17}	10,4439	-	179,1619	-	-168,7180	=	0,0			ξ_8	-	ξ_{12}	+	0,0	=	v_{17}	0,0113
H_{XIII}	-	H_{VIII}	-	h_{18}	=	v_{18}	49,6972	-	10,4439	-	39,2487	=	4,6		-	$\xi 8$	+	$\xi 13$	+	4,6	=	v_{18}	0,0041
H_{XII}	-	H_{XIII}	-	h_{19}	=	v_{19}	179,1619	-	49,6972	-	129,4601	=	4,6			ξ_{12}	-	ξ_{13}	+	4,6	=	v_{19}	0,0115
H_{XI}	-	H_{XIV}	-	h_{20}	=	v_{20}	95,2382	-	84,5788	-	10,6594	=	0,0			ξ_{11}	-	ξ_{14}	+	0,0	=	v_{20}	0,0261
H_{XIV}	-	H_{XV}	-	h_{21}	=	v_{21}	84,5788	-	141,1518	-	-56,5768	=	3,8			ξ_{14}	-	ξ_{15}	+	3,8	=	v_{21}	0,0203
H_{XII}	-	H_{XV}	-	h_{22}	=	v_{22}	179,1619	-	141,1518	-	38,0138	=	-3,7			ξ_{12}	-	ξ_{15}	+	-3,7	=	v_{22}	0,0125
H_{XV}	-	H_{XVI}	-	h_{23}	=	v_{23}	141,1518	-	156,6380	-	-15,4846	=	-1,6			ξ_{15}	-	ξ_{16}	+	-1,6	=	v_{23}	0,0078
H_{XVI}	-	H_{XIII}	-	h_{24}	=	v_{24}	156,6380	-	49,6972	-	106,9424	=	-1,6		-	ξ_{13}	+	ξ_{16}	+	-1,6	=	v_{24}	0,0078
H_{XVII}	-	H_X	-	h_{25}	=	v_{25}	132,1347	-	80,2234	-	51,9249	=	-13,6		-	ξ_{10}	+	ξ_{17}	+	-13,6	=	v_{25}	0,0075
H_{XVIII}	-	H_{XVII}	-	h_{26}	=	v_{26}	91,3675	-	132,1347	-	-40,7748	=	7,6		-	ξ_{17}	+	ξ_{18}	+	7,6	=	v_{26}	0,0081
H_{XVIII}	-	H_{XIV}	-	h_{27}	=	v_{27}	91,3675	-	84,5788	-	6,7887	=	0,0		-	ξ_{14}	+	ξ_{18}	+	0,0	=	v_{27}	0,0563
H_{XIX}	-	H_{XVIII}	-	h_{28}	=	v_{28}	130,3630	-	91,3675	-	38,9902	=	5,3		-	ξ_{18}	+	ξ_{19}	+	5,3	=	v_{28}	0,0060
H_{XVI}	-	H_{XIX}	-	h_{29}	=	v_{29}	156,6380	-	130,3630	-	26,2698	=	5,2			ξ_{16}	-	ξ_{19}	+	5,2	=	v_{29}	0,0054
H_{XVII}	-	H_{XIX}	-	h_{30}	=	v_{30}	132,1347	-	130,3630	-	1,7505	=	21,2			ξ_{17}	-	ξ_{19}	+	21,1	=	v_{30}	0,0047

RESULTS AND DISCUSSION

After correction the parametric equations were calculated, elevation corrections v measured and each line weight p value, as well as pv^2 sum were determined (Table 4).

Table 4

Data for leveling accuracy assessment

weight (p)	correction v	pv^2
0,00495	-1,10	0,0060
0,01168	-3,07	0,1101
0,01224	2,57	0,0808
0,00545	-7,66	0,3196
0,01376	4,87	0,3263
0,01096	2,36	0,0610
0,01440	-5,58	0,4483
0,04090	-1,17	0,0560
0,01084	2,40	0,0624
0,02330	-3,17	0,2342
0,34722	-0,15	0,0078
0,03738	-3,43	0,4398
0,03998	-3,13	0,3917
0,00786	-6,88	0,3721
0,01986	-0,04	0,0000
0,01254	-0,26	0,0008
0,01133	-1,80	0,0367
0,00407	7,51	0,2298
0,01153	3,48	0,1396
0,02614	-0,15	0,0006
0,02029	2,20	0,0982
0,01254	-4,83	0,2925
0,00777	-2,01	0,0314
0,00778	-1,18	0,0108
0,00751	-7,34	0,4047
0,00814	3,50	0,0997
0,05634	0,86	0,0417
0,00598	12,84	0,9860
0,00539	-1,20	0,0078
0,00474	17,67	1,4800
	Sum:	6,7763

The calculated value is used to describe the accuracy of the leveling network; it is for calculation of the leveling kilometric standard deviation S_{km}

$$S_{km}=\sqrt{\frac{[pv^2]}{n-t}}=\sqrt{\frac{6,7763}{30-19}}=0,785\text{ mm} \qquad (3)$$

where:

S_{km} – leveling kilometric standard deviation

n – number of lines

Since node 19 (fr1174) is located farthest from the selected leveling network starting point sr444, than its adjusted height weight, in the process of reduction of the equation system by Gauss algorithm is a coefficient at ξ_{19}. ξ_{19} is the last unknown, and at the same time this node adjusted the height weight and also the height standard deviation $S_{H19.}$

$$S_{H19}=\frac{S_{km}}{\sqrt{p_{19}}}=\frac{0,785}{\sqrt{0,0072}}=9,2\text{ mm} \qquad (4)$$

In the process of carrying out the entire leveling network adjustment with software NivNet, there was obtained the same standard deviation value for this node height. This indicates that the applied software for calculations provides authentic equalization results and their accuracy evaluation. Therefore, to reduce large amount of calculations, the rest of the node adjusted height standard deviations are determined by the computer program NivNet.

Table 5

Height standard deviations calculated from the starting point sr444

Leveling sign	Point height, m	Standard deviation, mm
Tp6968	12.65378	6.52
fr1463	13.40877	8.42
sr0352	87.50955	7.56
gr12387	72.78554	7.44
sm320	33.56510	5.90
fr3389	12.30377	3.35
gr0988	13.32823	4.03
sm0393	10.44087	4.22
sm0296	17.85190	4.12
gr1537	80.22040	6.94
sm0276	95.23634	6.31
gr1542	179.16068	6.80
fr50	49.69712	7.84
gr240	84.57710	6.88
fr3939	141.15170	7.26
fr1484	156.63834	8.55
gr6031	132.13794	8.54
sr218	91.36666	7.36
fr1174	130.36976	9.24

For practical use of the leveling network, it is important to know the height of the points and their accuracy. According to the Cabinet of Ministers rules Nr.879, as the starting point the century benchmark fr002 in Sloka was chosen; and then the leveling network nodal points adjusted height standard deviations were determined. Considering the above mentioned the leveling network node point height standard deviation valueswere calculated both, for the starting point sr444 and the century benchmark fr002. The obtained values are summarized in Table 6.

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	r	s	t	-pλ	
a	0,0279 ξ_1	-0,0049 ξ_2	-0,0122 ξ_3																	0,0168	a
b	-0,0049 ξ_1	0,0220 ξ_2	-0,0117 ξ_3	-0,0054 ξ_4																-0,0290	b
c	-0,0122 ξ_1	-0,0117 ξ_2	0,0377 ξ_3	-0,0138 ξ_4																0,0646	c
d		-0,0054 ξ_2	-0,0138 ξ_3	0,0302 ξ_4	-0,0110 ξ_5															-0,1480	d
e				-0,0110 ξ_4	0,0333 ξ_5	-0,0144 ξ_6				-0,0079 ξ_{10}										-0,0282	e
f					-0,0144 ξ_5	0,0927 ξ_6			-0,0374 ξ_9											-0,0862	f
g							0,4105 ξ_7	-0,3472 ξ_8	-0,0400 ξ_9											0,2160	g
h							-0,3472 ξ_7	0,3626 ξ_8				-0,0113 ξ_{12}	-0,0041 ξ_{13}							-0,0189	h
i						-0,0374 ξ_6	-0,0400 ξ_7		0,0899 ξ_9		-0,0125 ξ_{11}									-0,0253	i
j					-0,0079 ξ_5					0,0353 ξ_{10}	-0,0199 ξ_{11}						-0,0075 ξ_{17}			0,1239	j
k									-0,0125 ξ_9	-0,0199 ξ_{10}	0,0585 ξ_{11}			-0,0261 ξ_{14}						-0,0069	k
l								-0,0113 ξ_8				0,0353 ξ_{12}	-0,0115 ξ_{13}		-0,0125 ξ_{15}					0,0067	l
m								-0,0041 ξ_8				-0,0115 ξ_{12}	0,0234 ξ_{13}			-0,0078 ξ_{16}				-0,0215	m
n											-0,0261 ξ_{11}			0,1027 ξ_{14}	-0,0203 ξ_{15}			-0,0563 ξ_{18}		0,0771	n
o												-0,0125 ξ_{12}		-0,0203 ξ_{14}	0,0406 ξ_{15}	-0,0078 ξ_{16}				-0,0434	o
p													-0,0078 ξ_{13}		-0,0078 ξ_{15}	0,0210 ξ_{16}			-0,0054 ξ_{19}	0,0281	p
r										-0,0075 ξ_{10}							0,0203 ξ_{17}	-0,0081 ξ_{18}	-0,0047 ξ_{19}	-0,0640	r
s														-0,0563 ξ_{14}			-0,0081 ξ_{17}	0,0704 ξ_{18}	-0,0060 ξ_{19}	0,0298	s
t																-0,0054 ξ_{16}	-0,0047 ξ_{17}	-0,0060 ξ_{18}	0,0161 ξ_{19}	-0,0959	t
	2,7985	**6,9982**	**4,9662**	**9,8411**	**3,8978**	**1,1731**	**-3,1718**	**-3,0245**	**-0,8980**	**-2,9806**	**-1,8425**	**-1,2279**	**-0,1112**	**-1,6914**	**-0,0952**	**0,3102**	**3,2744**	**-0,8275**	**6,7080**		
	ξ1	**ξ2**	**ξ3**	**ξ4**	**ξ5**	**ξ6**	**ξ7**	**ξ8**	**ξ9**	**ξ10**	**ξ11**	**ξ12**	**ξ13**	**ξ14**	**ξ15**	**ξ16**	**ξ17**	**ξ18**	**ξ19**		

Figure 5. Normal equations unknown coefficients

Table 6
Height standard deviations calculated from the starting point fr002

Leveling sign	Point height, m	Standard deviation, mm
Tp6968	12.65252	6.04
fr1463	13.40750	8.27
sr0352	87.50828	7.39
gr12387	72.78428	7.49
sm320	33.56384	6.41
fr3389	12.30250	4.55
sr444	2.96874	3.25
gr0988	13.32696	5.10
sm0393	10.43961	5.25
sm0296	17.85063	5.15
gr1537	80.21913	7.51
sm0276	95.23508	6.98
gr1542	179.15942	7.46
fr50	49.69585	8.42
gr240	84.57583	7.50
fr3939	141.15043	7.86
fr1484	156.63707	9.07
gr6031	132.13668	9.03
sr218	91.36539	7.94
fr1174	130.36850	9.71

In general, the performed leveling will give the opportunity to use the calculated elevation values for the existing height system update and successful inclusion in the European Vertical Reference System (Sacher et al., 1999).

As well as the given leveling product – elevation values are useable as support for various public sector research and development. For example by the Earth crust vertical movement studies, updating the cartographic material components of height and other (Lazdāns et al., 2009).

CONCLUSIONS

1. Furthest from the century benchmark fr002 the fundamental benchmark 1174 is located in Zilupe, which height standard deviation is 9,7 mm and the fundamental benchmark 1463 in Jurkalne, which height standard deviation is 8,2 mm.
2. Considering the current leveling network standard deviation S = 0,785 mm/km, that affects the accuracy of nodal points, to recognize the causes, there is a further need to determine the leveling systematic error and study its influencing factors.
3. The leveling network point height accuracy may directly affect the lower classes leveling accuracy.
4. The nodal point height standard deviation is required for calculations of the geoid model latest versions.

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