



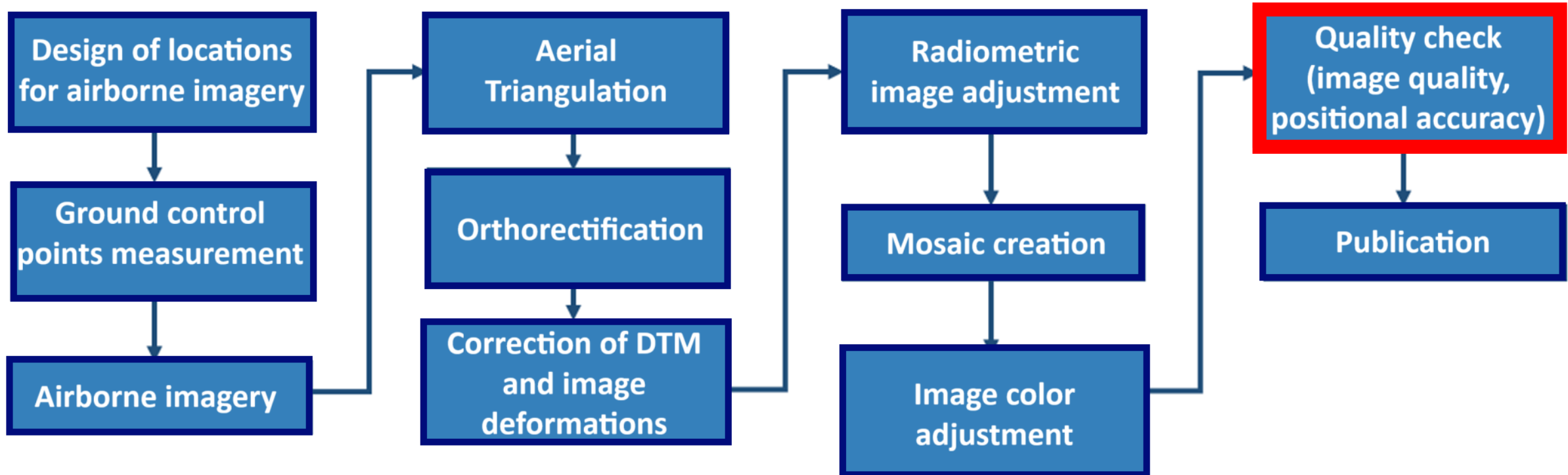
Quality check of topographic data provided by the UGKK SR

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Bratislava, Slovakia, 9 October 2024



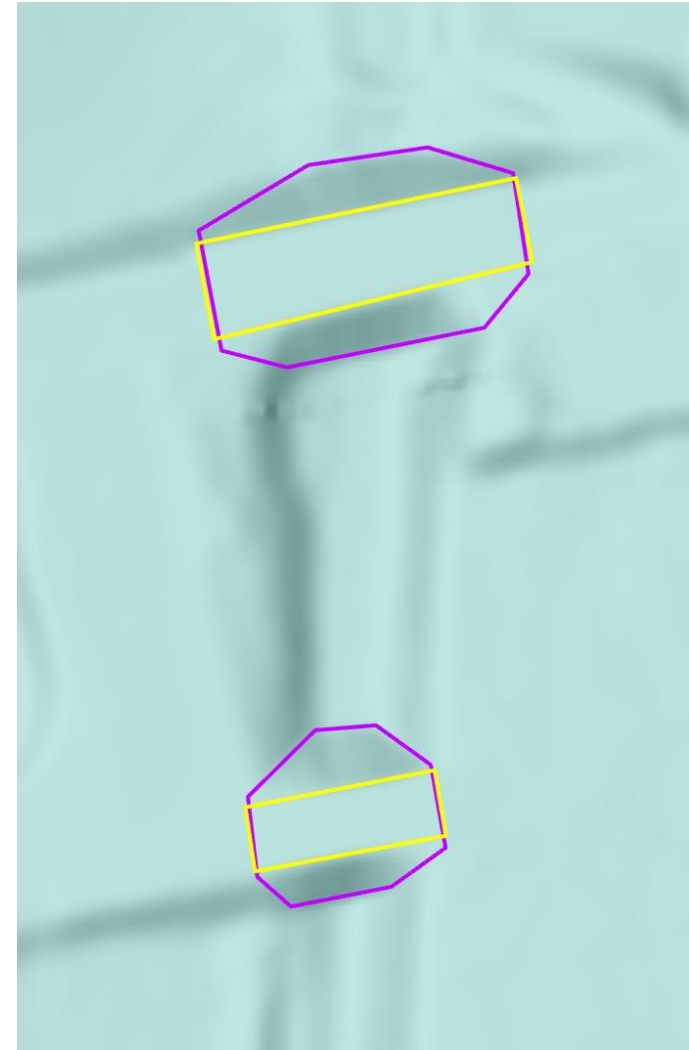
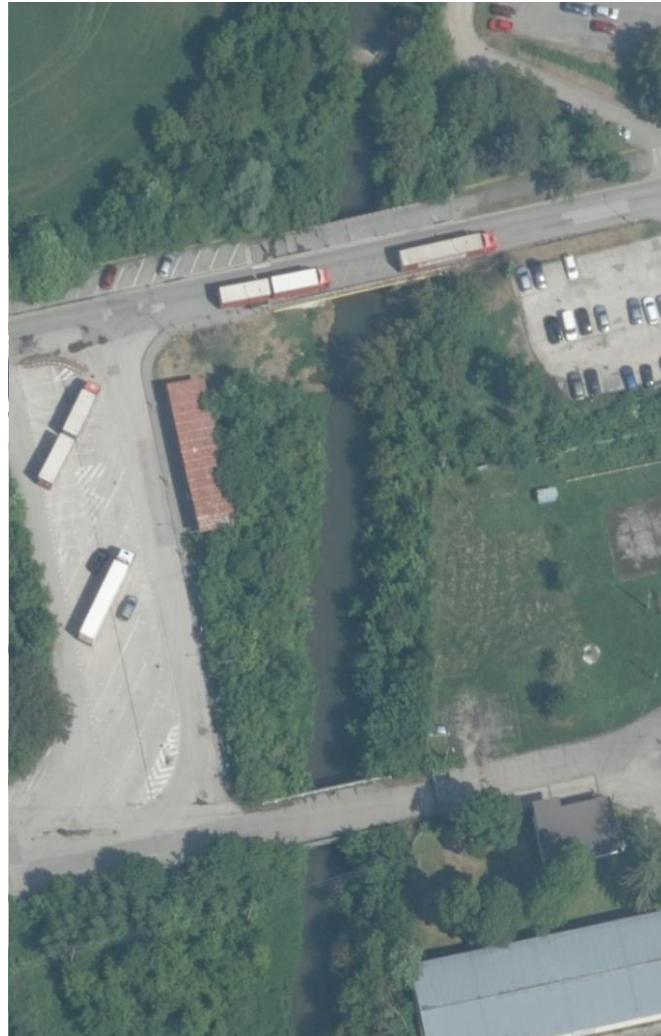
Technological process of creating a orthophotomosaic





Check of image deformations after orthorectification

- Visual check of orthophotos after orthorectification.
- Identified deformations of objects on the image in places such as bridges.
- Correction of the DTM used for orthorectification e.g. modeling of missing bridge objects. Then orthorectification is done again.





Visual check of image quality

- Performed on the selected control tiles.
- Requirements:
 - Area of clouds together with the shadow cast by clouds on the controlled territory is less than 2% of its area.
 - Seamlines used for the orthophotomosaic creation are not visible.
 - Along the seamlines there is a brightness, color and contrast presentation of the image without visible differences.



Example of errors resulting from incorrect alignment of seamlines



Example incorrect color properties of the image around the seamlines



Position accuracy control - visual

- Performed on the selected control tiles.
- Checked is the compliance of the position of the objects on the orthophotomosaic with the cadastral map - mainly the footings of buildings and roads are used for control.





Position accuracy control - numerical

Ground control points measurement

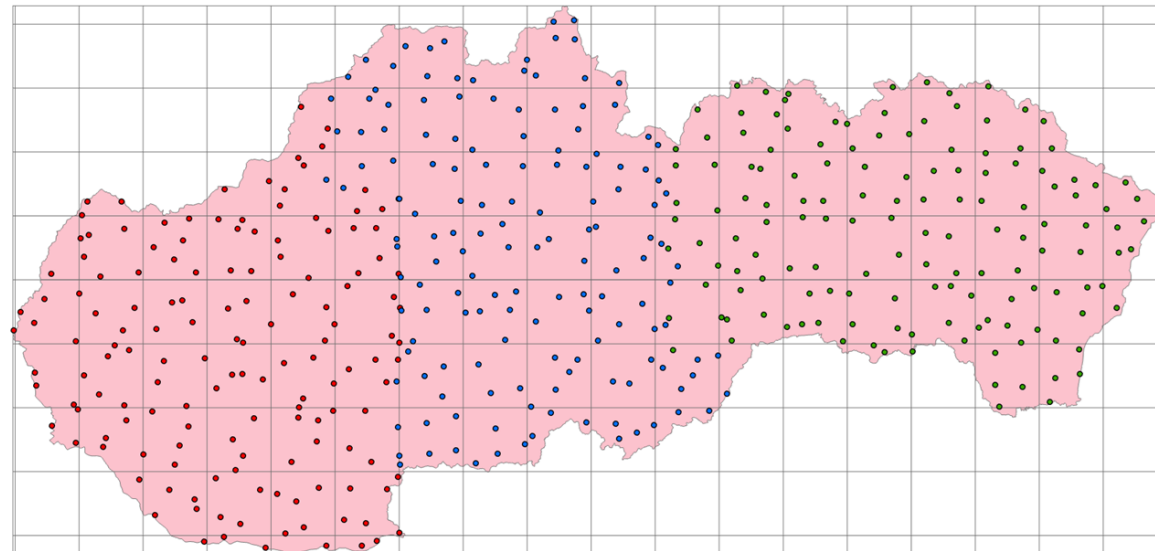
- Clearly identifiable points (objects) on the image and in real terrain.
- Measurement method: GNSS (RTK, static) using SKPOS.
- Positional accuracy: $m_{xy} < 0,04$ m, vertical accuracy: $m_h < 0,06$ m.





Position accuracy control - numerical

- Controled area is divided into a regular grid.
- At least 1 control point is in each cell of grid.
- Entire territory of Slovakia: 448 control points.
- Spatial distribution of control points takes into account types of terrain according to its vertical division (lowlands, highlands).
- Coordinates of each control point on the orthophotomosaic are measured independently at least 3 times.

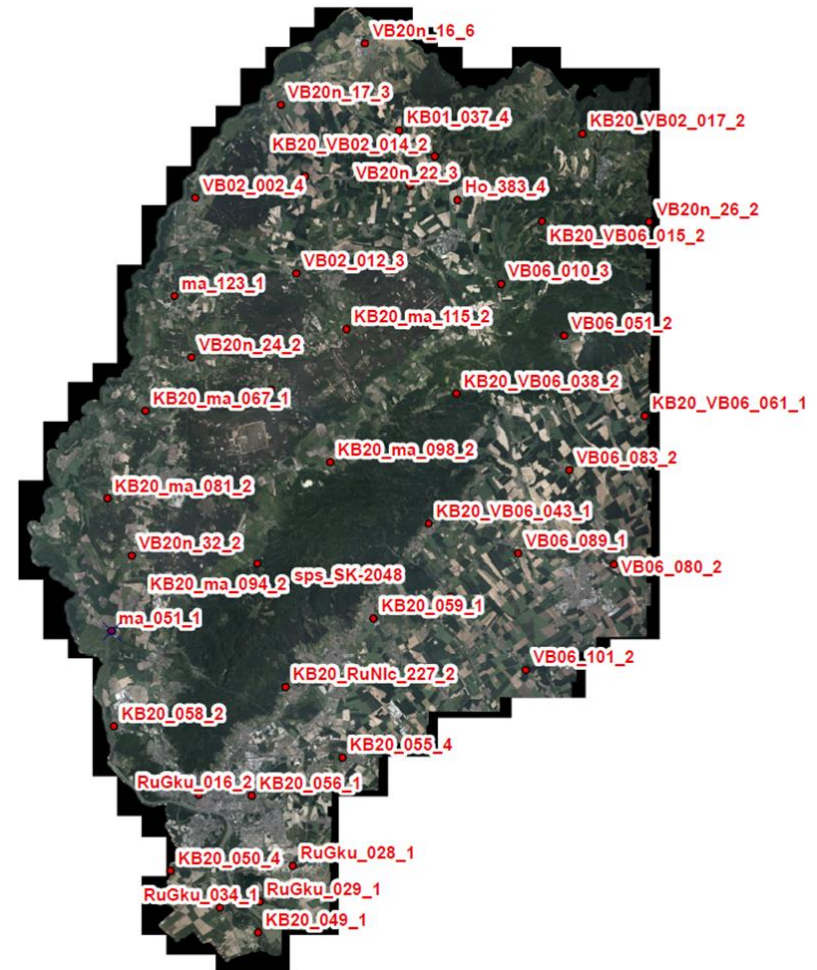




Position accuracy control - numerical

- Accuracy control on 3 levels:
 - locality

Locality

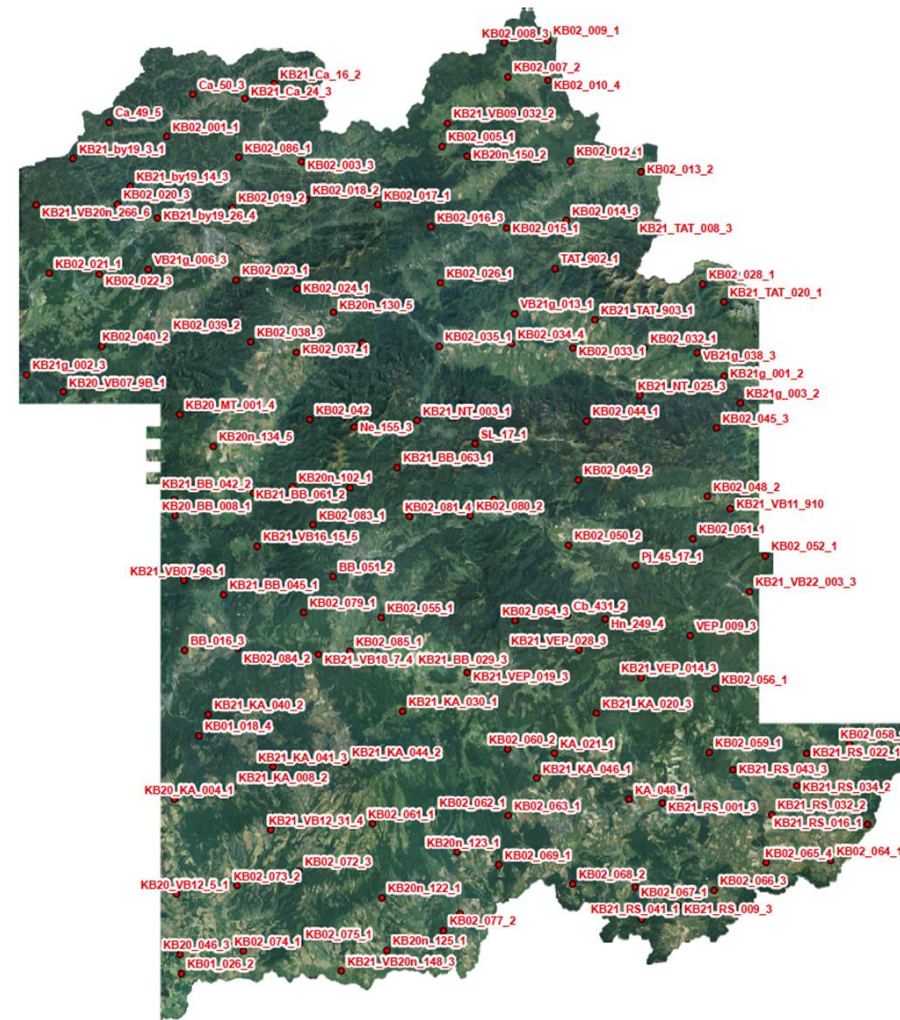




Position accuracy control - numerical

- Accuracy control on 3 levels:
 - locality
 - western, central or eastern part of Slovakia

Central part of Slovakia

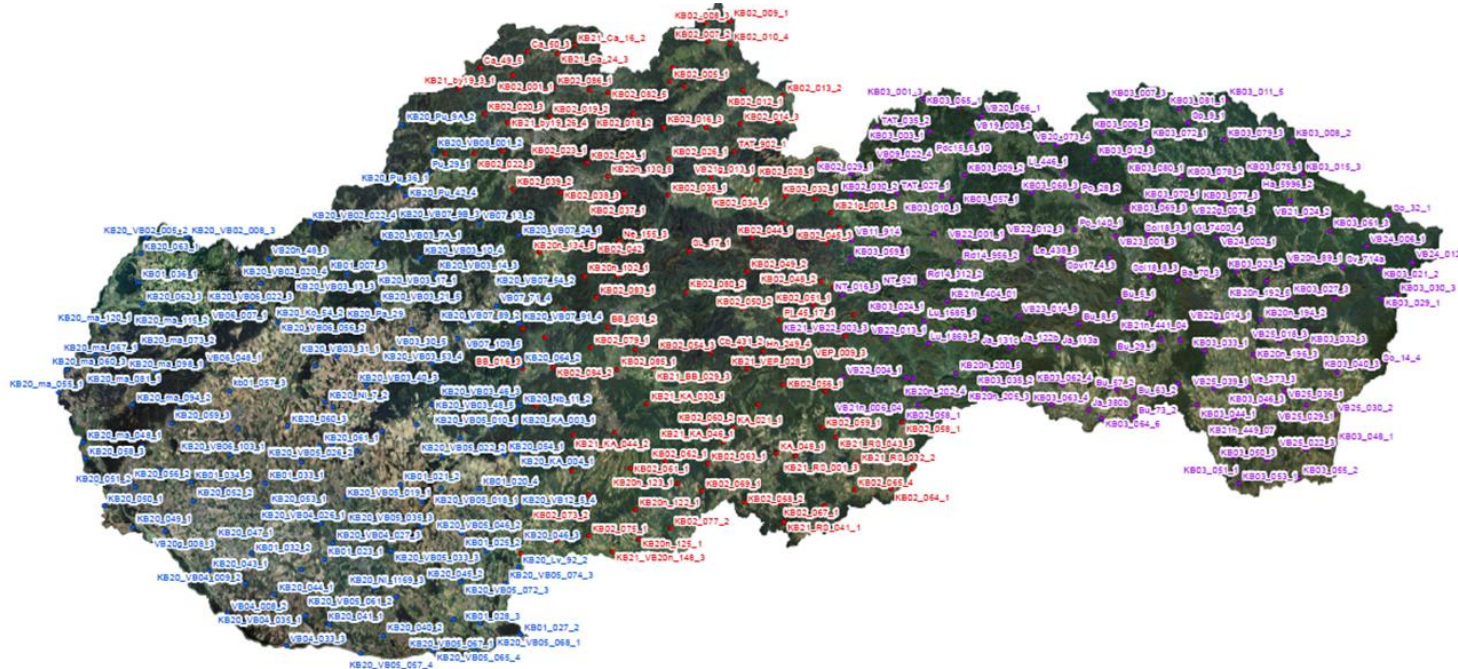




Numerical position accuracy control

- Accuracy check on 3 levels:
 - locality
 - western, central or eastern part of Slovakia
 - entire territory of Slovakia

Entire territory of Slovakia





Position accuracy control - numerical

- Positional accuracy is calculated according to the following formulas:

Positional error in the x coordinate:

$$RMSE_x = \sqrt{\frac{\sum_{i=1}^n \Delta x_i^2}{n}}$$

Positional error in the y coordinate:

$$RMSE_y = \sqrt{\frac{\sum_{i=1}^n \Delta y_i^2}{n}},$$

Δx , Δy – differences of the coordinates measured on the orthophotomosaic and the reference coordinates of control points,
 n – number of control points.

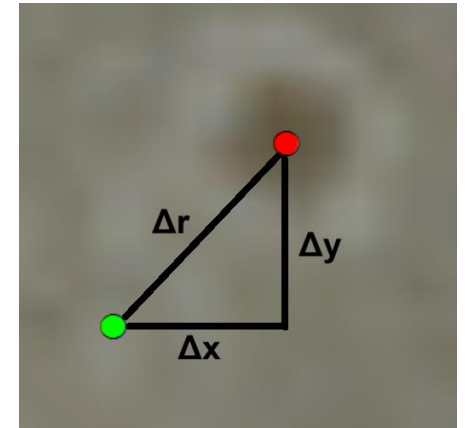
Positional error $RMSE_{xy}$:

$$RMSE_{xy} = \sqrt{RMSE_x^2 + RMSE_y^2}$$

CE95 (Circular error 95%):

$$CE95 = 1,7308 * RMSE_{xy}$$

represents the magnitude of an error which will not be exceeded in 95% of cases.





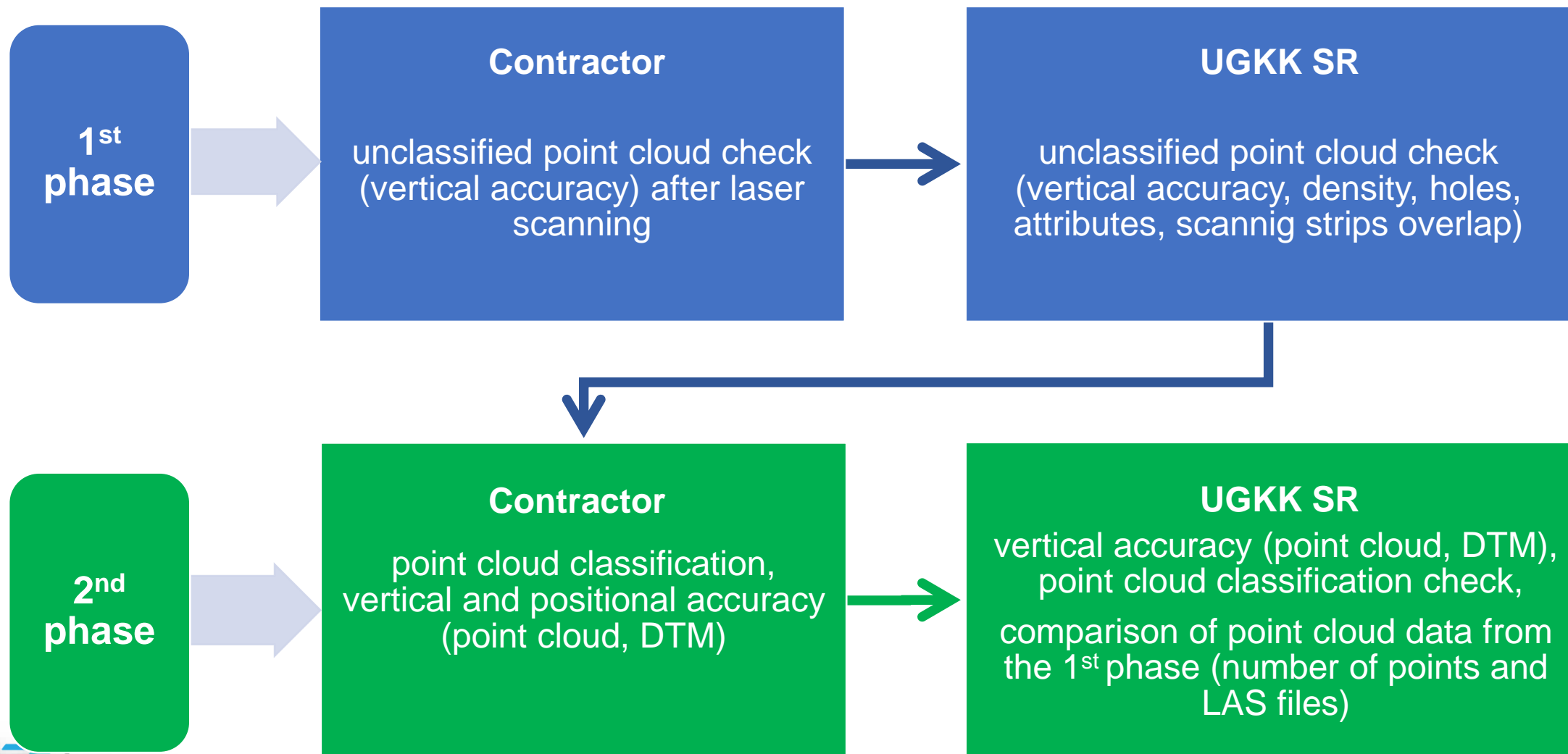
Position accuracy control - results

- Orthophotomosaic 2017 – 2019 (GSD=25 cm):
 - $RMSE_{xy} = 0,30$ m
 - CE95 = 0,52 m
- Orthophotomosaic 2020 – 2022 (GSD=20 cm):
 - $RMSE_{xy} = 0,21$ m
 - CE95 = 0,26 m
- Orthophotomosaic 2023 (GSD=15 cm):
 - $RMSE_{xy} = 0,17$ m
 - CE95 = 0,29 m





Quality check procedure





Positional accuracy control

Point cloud

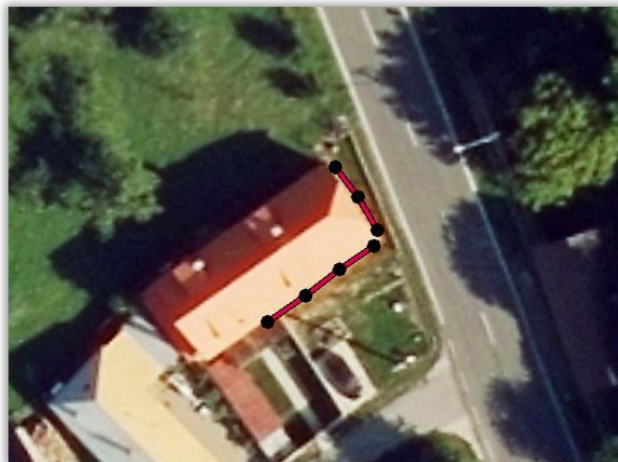
- Positional accuracy is checked by measuring the shifts of the point cloud from reference control points located on buildings with vertical walls.

Positional error:

$$m_{xy} = \sqrt{\frac{\sum_{p=1}^n \Delta xy}{n}},$$

Δxy - horizontal distance of a point from point cloud clearly identified on a control object from the vertical plane of this object determined by the control measurement,

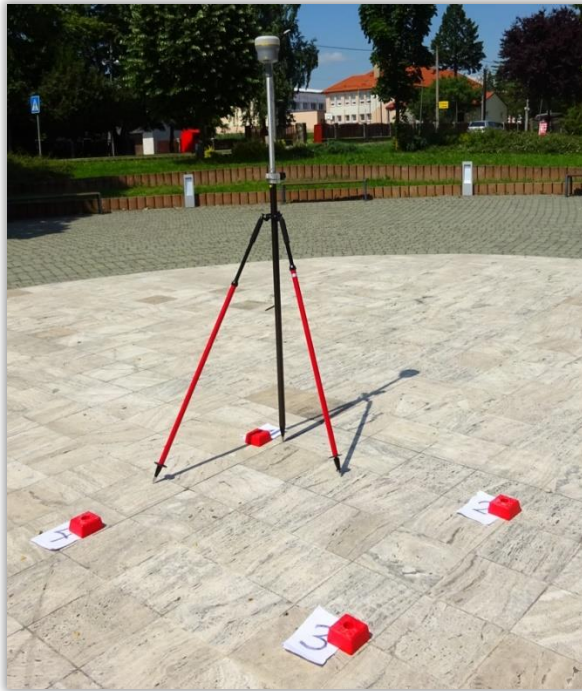
n – number of control points.



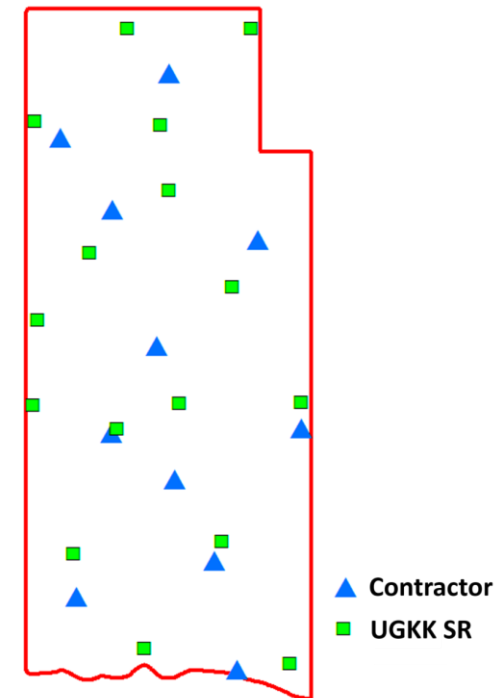


Vertical accuracy control

- Vertical accuracy is checked on the control grid, which consists of 4 points at the distance of 1 m measured by the GNSS methods on open paved surfaces.



Control grid



Control grids in locality 9
from 1st ALS cycle



Vertical accuracy control

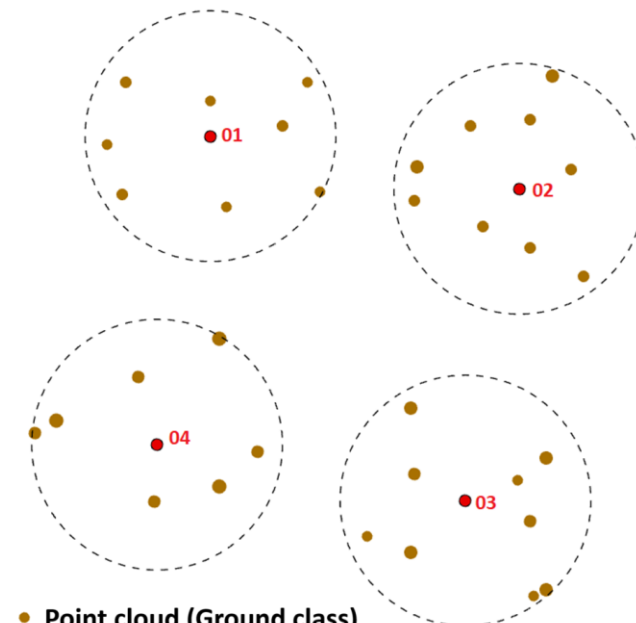
Point cloud

- Vertical accuracy is checked on points from Ground class which are located within a distance of 40 cm from the control grid points.
 - the average height difference $\overline{\Delta h}$ between the height of the cloud points and the height of the control grid points is calculated.

Vertical error:

$$m_h = \sqrt{\frac{\sum_{i=1}^n \Delta \bar{h}_i^2}{n}}$$

n - number of control grids.



● Point cloud (Ground class)

● Control grid point

Control grid



Vertical accuracy control

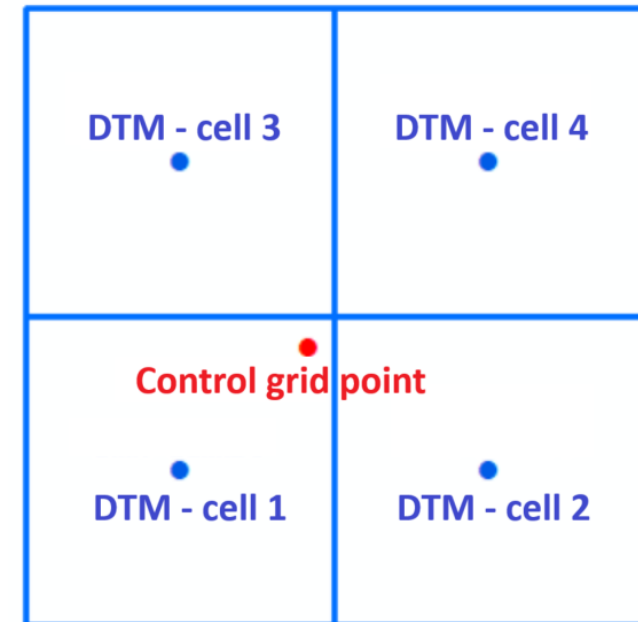
Digital terrain model

- Vertical accuracy is checked on the 4 nearest DTM cells in the vicinity of each control grid point.
 - the average height difference $\overline{\Delta H}$ between the height of DTM cells and the height of the control grid points is calculated.

Vertical error:

$$m_H = \sqrt{\frac{\sum_{i=1}^n \Delta \bar{H}_i^2}{n}}$$

n - number of control grids.



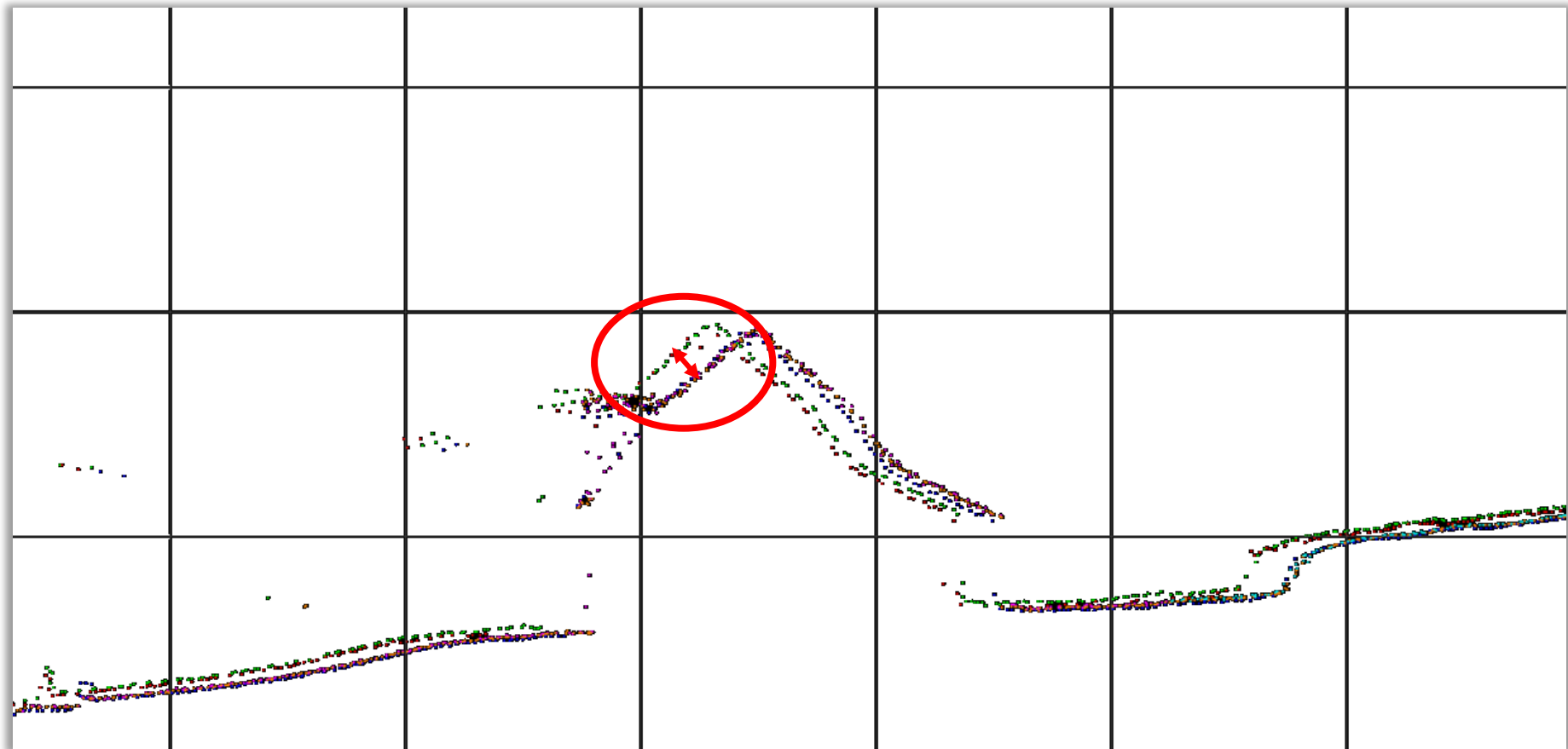
Control grid point with nearest DTM cells



Vertical and positional accuracy

- Testing the vertical and positional accuracy (shifts) of point clouds between neighbouring scanning strips and ALS localities.

Example of positional shift between scanning strips





Positional and vertical accuracy control - results

- Required accuracies:
 - 1st cycle - Point cloud: $m_{xy} \leq 0,30$ m (ETRS89-TM34), $m_h \leq 15$ m (ETRS89-h), DTM: $m_H \leq 0,25$ m (Bpv)
 - 2nd cycle - Point cloud: $m_{xy} \leq 0,20$ m (ETRS89-TM34), $m_h \leq 10$ m (ETRS89-h)
 - Example results from localities 31-42 from 1st ALS cycle:

Point cloud

Locality	Vertical error m_{xy} [m]	Positional error m_h [m]
31	0,08	0,09
32	0,04	0,10
33	0,09	0,10
34	0,08	0,09
35	0,03	0,09
36	0,03	0,08
37	0,01	0,05
38	0,03	0,05
39	0,03	0,07
40	0,03	0,10
41	0,06	0,12
42	0,03	0,10

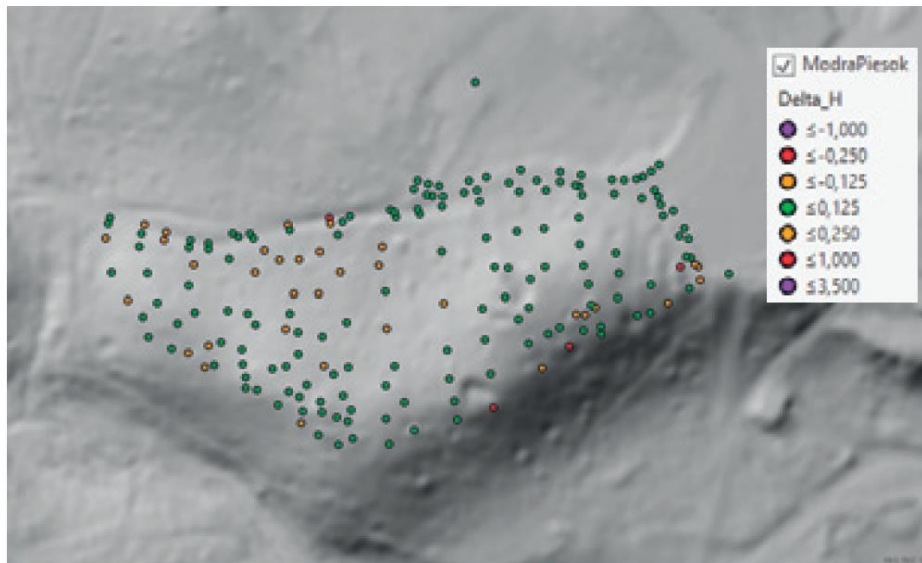
DTM (Bpv)

Locality	Vertical error m_H [m]
31	0,13
32	0,04
33	0,10
34	0,16
35	0,03
36	0,03
37	0,02
38	0,03
39	0,03
40	0,04
41	0,06
42	0,03



Vertical accuracy control on unpaved surfaces

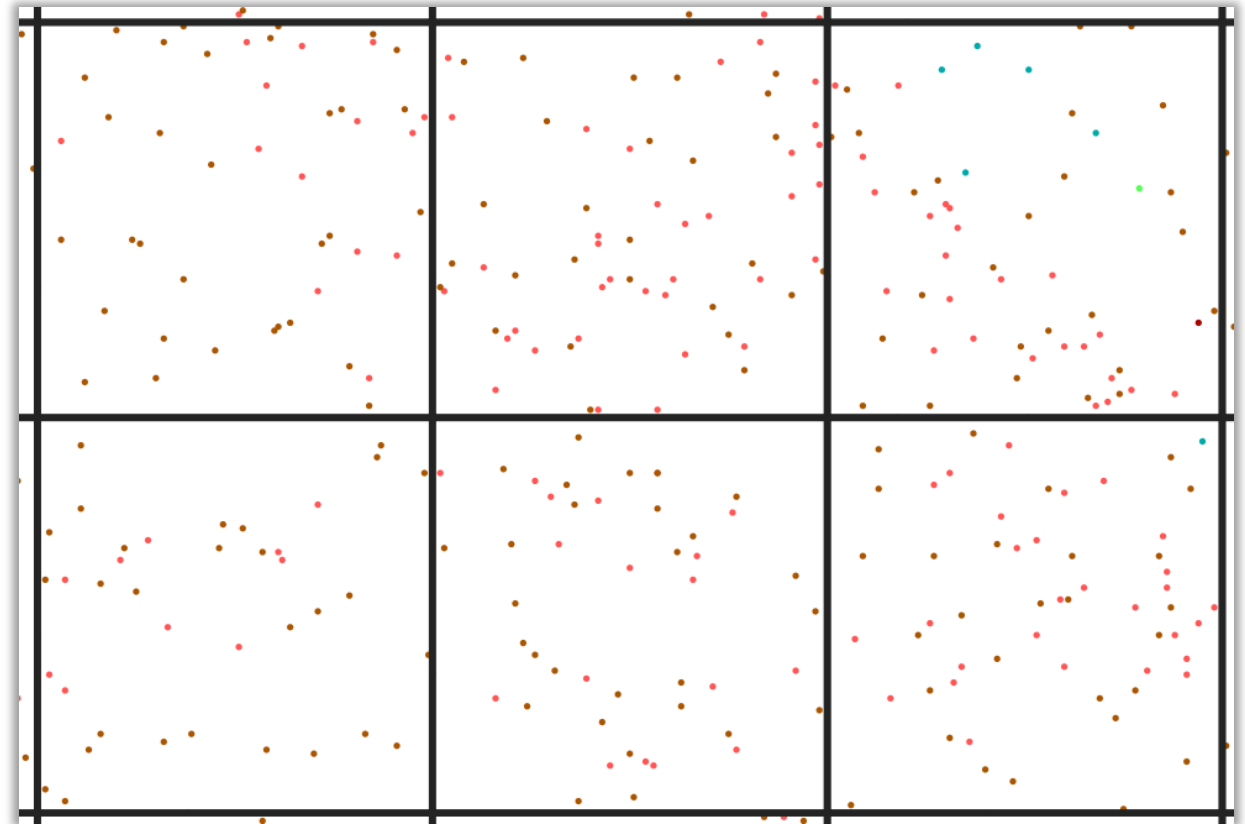
- Testing of the vertical accuracy of DTM on unpaved surfaces comparing with data provided by commercial surveyors or from various research tasks.
- Results:
 - in built-up areas: $m_H < 0,15$ m
 - in the fields: $m_H < 0,25$ m
 - in forest areas: $m_H < 0,50$ m





Point cloud density check

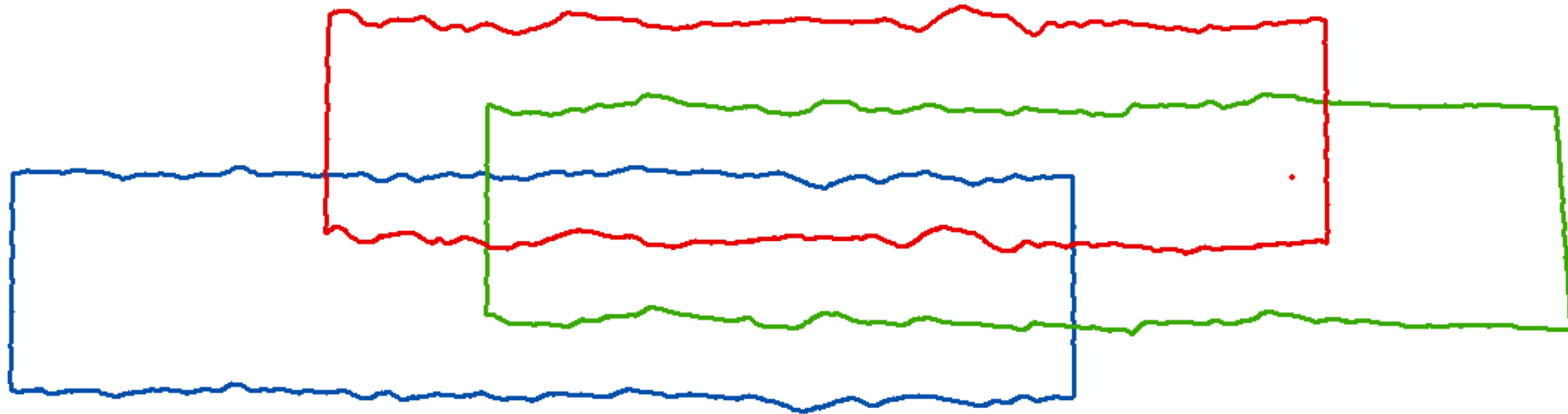
- Testing the density (number of points) of point cloud per 1 m².
- Requirements on point cloud density:
 - 1st ALS cycle: min. 5 points per m²
 - 2nd ALS cycle: min. 15 points per m²
- Achieved point cloud density:
 - 1st ALS cycle: 15-52 points per m²
 - 2nd ALS cycle: 34-45 points per m²





Scanning strips overlap check

- Testing the overlap of neighbouring scanning strips.
- Requirements on overlapping:
 - 1st ALS cycle: more than 40%
 - 2nd ALS cycle: more than 50%





Point cloud classification check

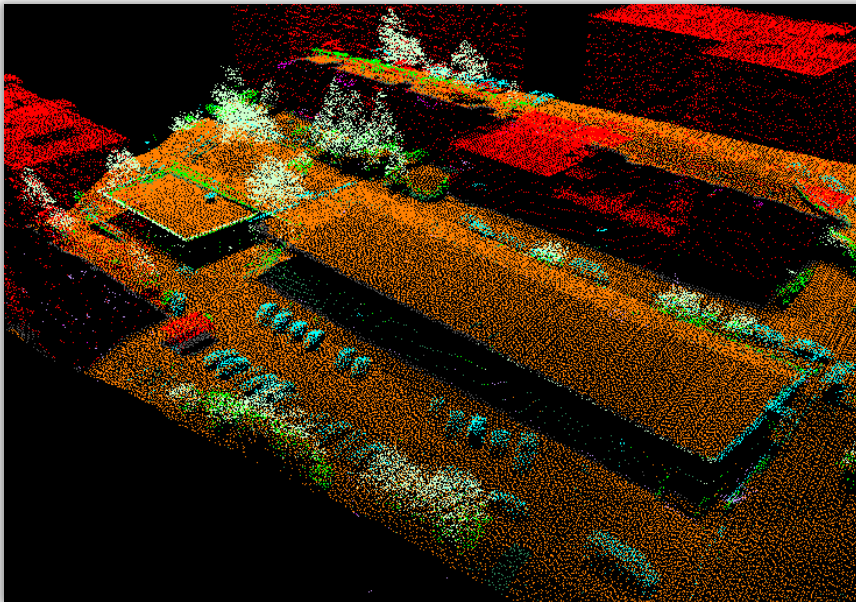
- Testing the correctness of the point cloud classification.
- Classification classes:
 - **1st ALS cycle:**
 - **Compulsory classification** into 2 classes - 01 Unclassified, 02 Ground.
 - **Optional classification** into 10 classes - 01 Unclassified, 02 Ground, 03 Low vegetation, 04 Medium vegetation, 05 High vegetation, 06 Building, 07 Low point (Noise), 09 Water, 17 Bridge deck and 18 Hight Noise.
 - **2nd ALS cycle:**
 - **Compulsory classification** into 10 classes - 01 Unclassified, 02 Ground, 03 Low vegetation, 04 Medium vegetation, 05 High vegetation, 06 Building, 07 Low point (Noise), 09 Water, 17 Bridge deck and 18 Hight Noise.
 - **Optional classification** into 12 classes - 01 Unclassified, 02 Ground, 03 Low vegetation, 04 Medium vegetation, 05 High vegetation, 06 Building, 07 Low point (Noise), 09 Water, 17 Bridge deck, 18 Hight Noise, 14 Power lines (Wire) and 15 Tower.
- **Classification accuracy requirements:**
 - Ground class: 99,5%
 - Other classes: 90% in the 1st ALS cycle, 95% in the 2nd ALS cycle



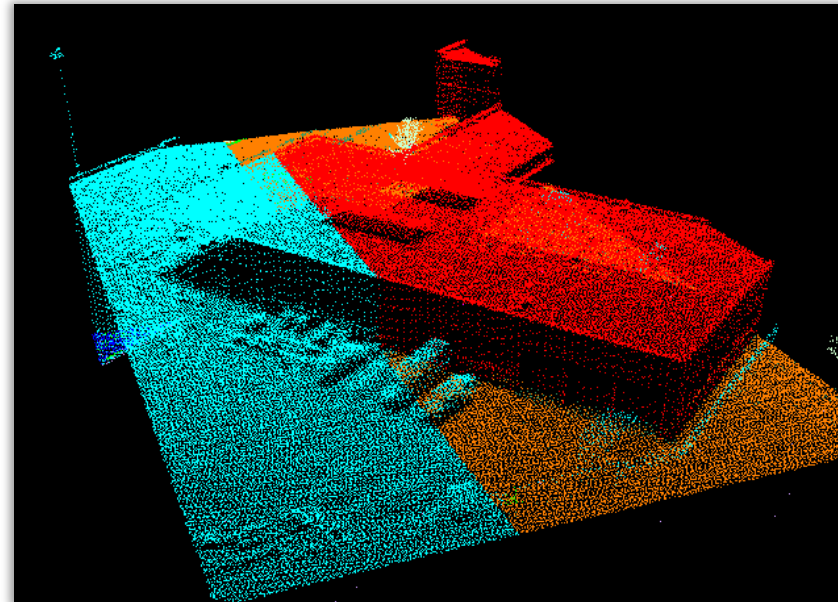
Point cloud classification check

- Examples of incorrectly classified points

Roofs of buildings in the Ground class



Building part in the Unclassified class

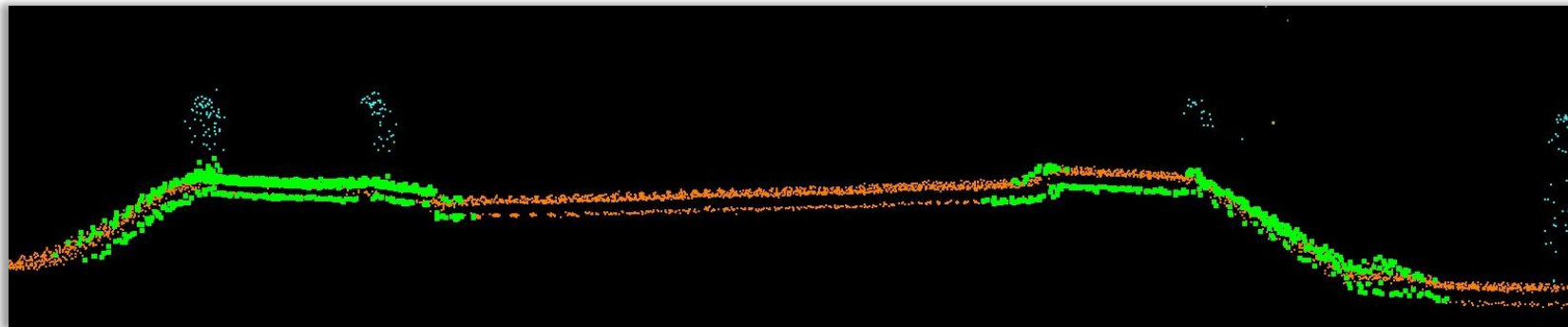
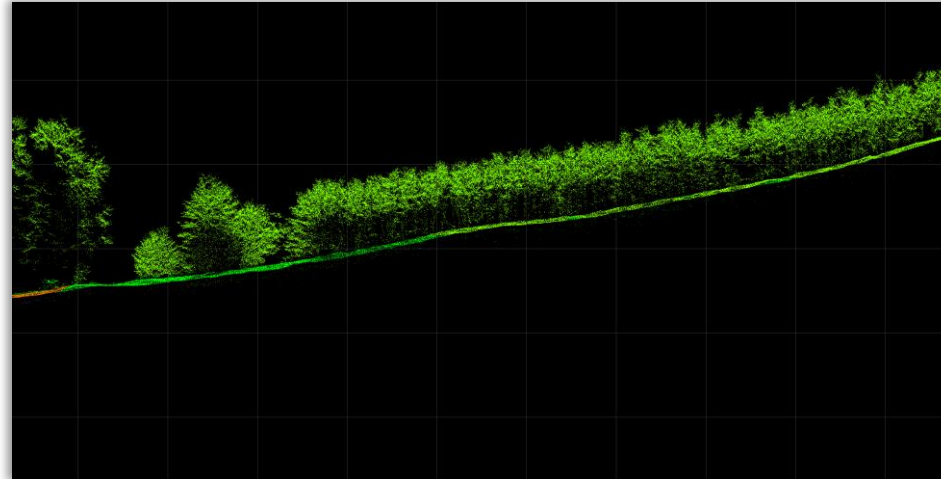




Point cloud classification check

- Examples of incorrectly classified points

Ground in the Vegetation classes

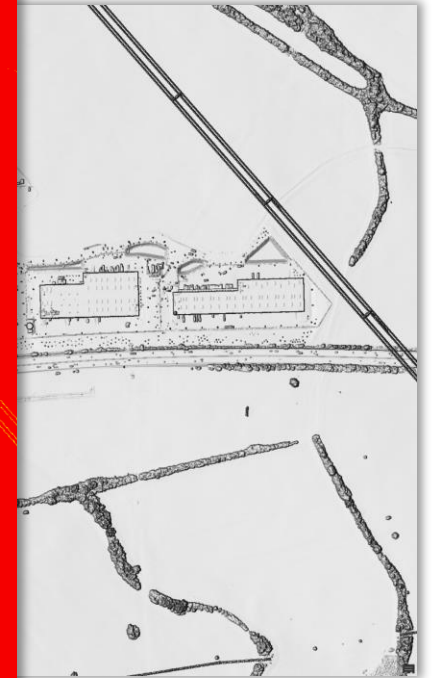
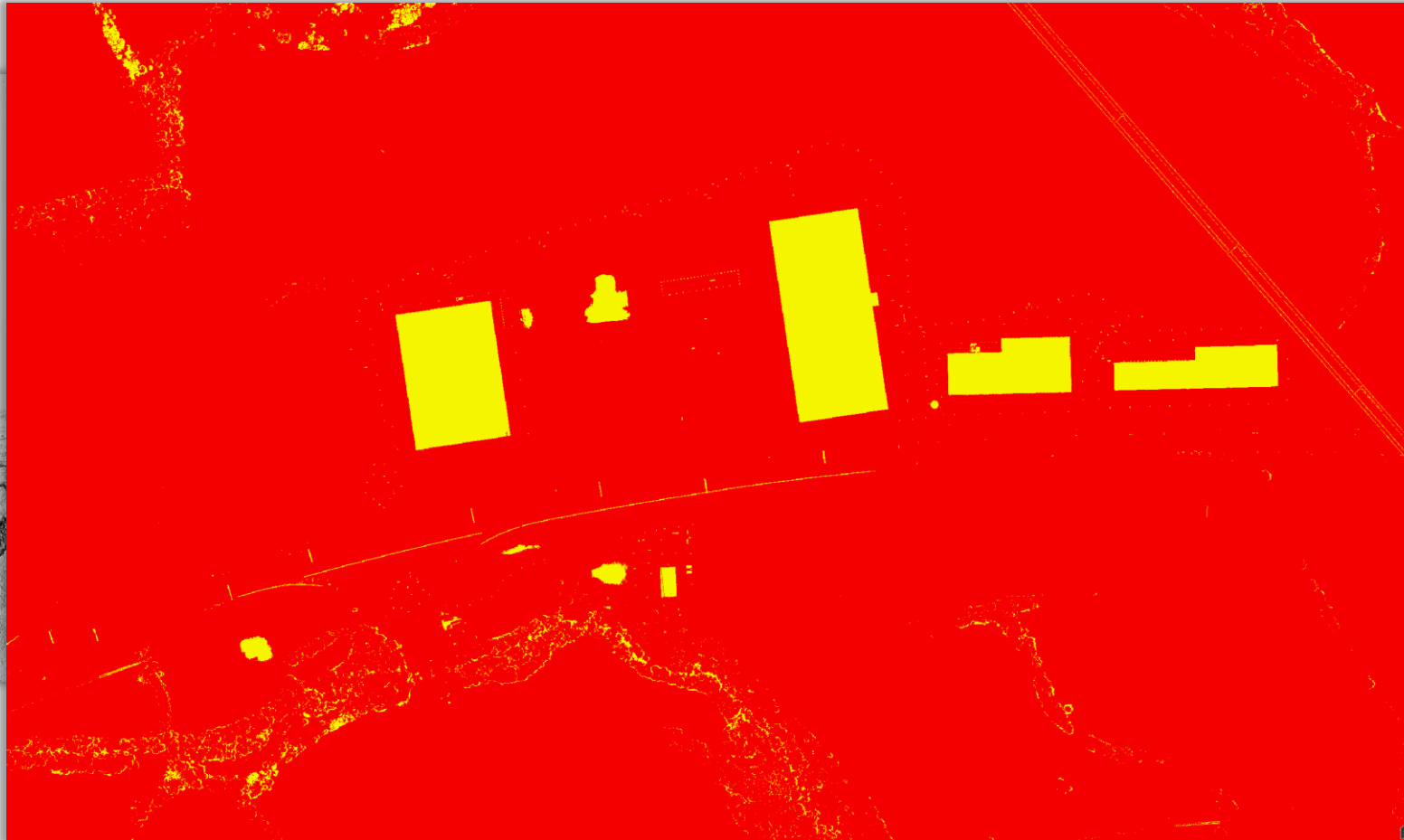
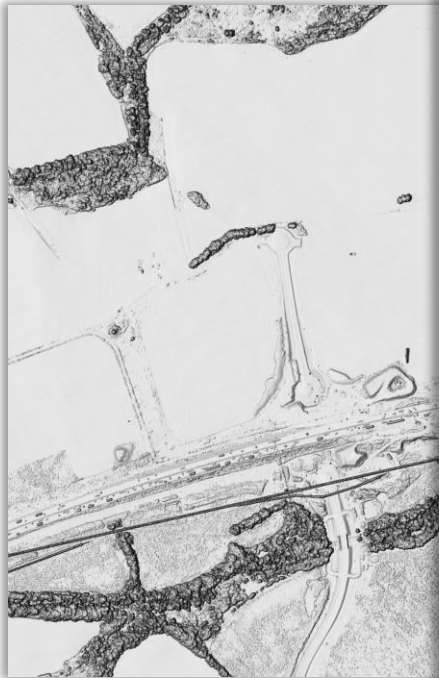




Comparison of data from 1st and 2nd ALS cycle

- Check the changes between 1st and 2nd cycle on DSM.

Difference raster between DSMs

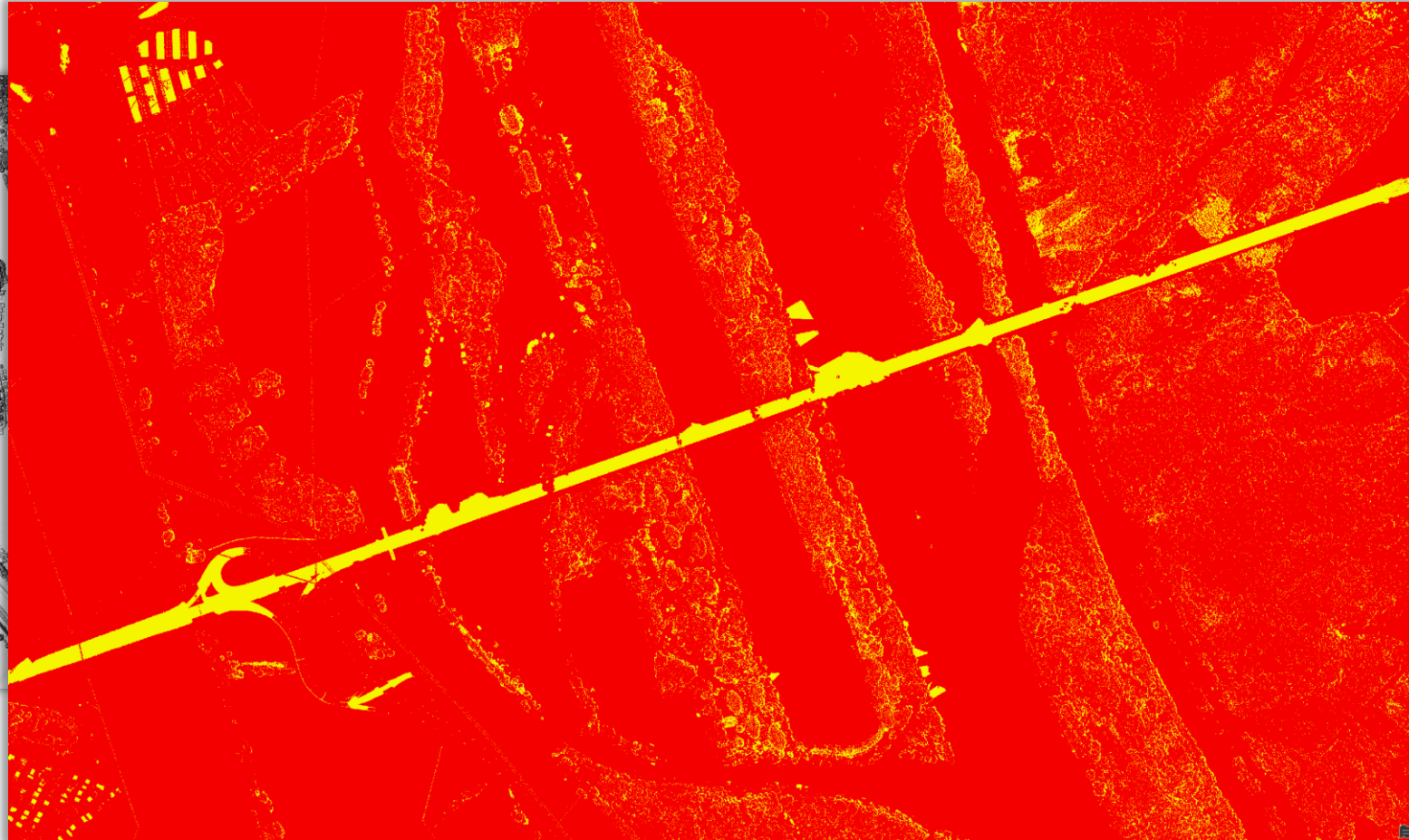




Comparison of data from 1st and 2nd ALS cycle

- Check the changes between 1st and 2nd cycle on DSM.

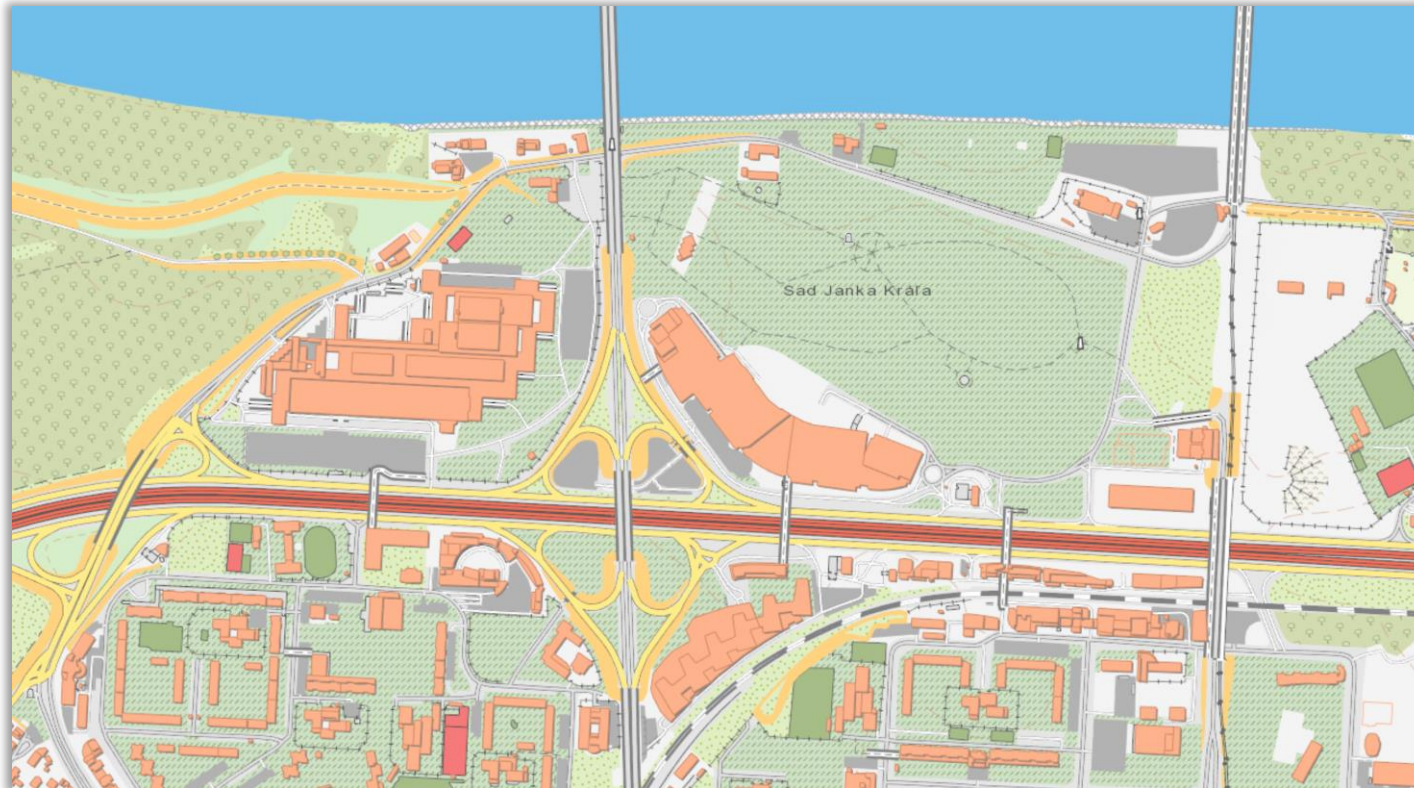
Difference raster between DSMs





ZBGIS

- Geodatabase which contains spatial topographic data about the territory of Slovakia defined by the ZBGIS Feature Catalogue (more than 100 feaature classes).
 - buildings, roads, railways, bridges, power lines, towers, watercourses, water bodies, etc.
- used in state and public administration GIS, creation of state basic and thematic maps





ZBGIS quality check

- Data quality check is based on the technical standards STN EN ISO 19157-1: Geographic information. Data quality.

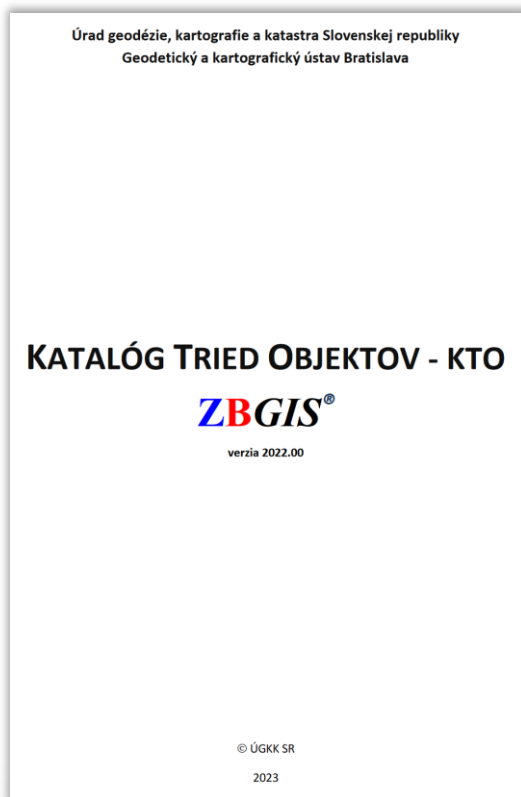
Elements of the quantitative side of quality		Scope of implementation
Completeness	Adding Omission	over the controlled area
Logical consistency	Domain consistency. Topological consistency	over the controlled area
Positional accuracy	Absolute positional accuracy Positional accuracy of raster data	over the controlled area
Time accuracy	Time validity	over the controlled area 5% of objects from each feature class
Thematic accuracy	Correctness of the classification Correctness of non-quantitative attributes Accuracy of quantitative attributes	over the controlled area 5% of objects from each feature class

ZBGIS – 1st phase of quality check



Completeness

- ZBGIS must contain all the objects listed in ZBGIS Feature Catalogue which existed during the period of ZBGIS creation/updation and which correspond to the specified spatial resolution.
- Control method – visual identification of the entire controlled area → comparison of ZBGIS data with other available data sources. It is performed over the orthophoto map, DTM/DSM or directly in the field.



Obsah	
VŠEOBECNÉ ATRIBÚTY	11
OBJEKTY 3D POLOHOPISU	14
AK160 Amfiteáter	14
AK020 Atrakcia v zábavnom parku, akvaparku	15
AK170 Bazén, požiarňa nádrž	16
AL116 Božie muky, križ	17
AP040 Brána, závara	17
BH070 Brad	18
AL015 Budova	19
AL101 Búda, chatrč	24
AP030 Cesta	25
AK130 Dostihová a iné dráhy	28
AT030 Elektrické vedenie	29
BH075 Fontána	30
ZD040 Geografický názov	31
Historický geografický názov	36
Variálny geografický názov	41
ZD040 Geografický názov - Katastrálne územie	42
ZD040 Geografický názov - Obec	44
GN-Obec (počet obyvateľov)	46
ZD040 Geografický názov - Časť obce	47
ZD040 Geografický názov - Okres	49
ZD040 Geografický názov - Kraj	50
ZD040 Geografický názov - Slovenská republika	51
BI040 Hať, stávidlo	52
EA055 Chmeľnica	53
AP050 Chodník	54
AK040 Ihrisko	55
Katastrálne územie	56
DB030 Jaskyňa	58
AF010 Kamin	60
BA051 Koruna hradze	62
FA002 Kraj	62
EB020 Kroviny, húštiny	63
AQ010 Lanovka, vleč	64
EC015 Les	65
EB010 Lúka	66
BH015 Močiar, slanisko	67
AQ040 Most	68
BB082 Nakladacia, vykladacia rampa	70
DB090 Násyp	72
OAO10 Neidentifikovateľné objekty	73
DA020 Neúrodná pôda	74
FA004 Obec	75
AM020 Obilné silo, sypka	77
FA003 Okres	78

AH010 Opevnenie, hradba, obranný val	79
EA010 Orná pôda	80
AL261 Ostatné objekty	81
EA040 Ovocný sad, záhrada	84
AQ140 Parkovisko	85
BI041 Plavebná brána	86
BI030 Plavebná komora	87
SA021 Plocha bez typického využitia	87
GB007 Plocha letiska	88
SA010 Plocha vodného toku	90
FC042 Plochy okolo liniových objektov	91
AL070 Plot	91
AL130 Pomník	93
Pomocná plocha	94
BH170 Prameň	95
AQ065 Priecestie	96
EC040 Priesek	97
ZB060 Referenčný geodetický bod	97
AC030 Sedimentácia nádrž	101
AM032 Skladka materiálu	102
FA001 Slovenská republika	103
AM011 Stena lomu	104
AT040 Stĺp, stĺžiar elektrického vedenia	105
AQ020 Stĺp lanovky	106
FA015 Strelnica	107
EC030 Strom	108
AM050 Studňa	109
AM070 Tank na uskladnenie kvapalín alebo plynov	110
AK050 Tenisový kurt	112
AD030 Transformátor	113
EB015 Trávnatý a krovinatý porast	113
AK110 Tribuna	114
EC016 Úžitková zeľ	116
AL241 Veža	117
EA050 Vinica	118
BH080 Vodná plocha	119
BH140 Vodný tok	120
AM080 Vodojem	122
BH180 Vodopád	124
CA010 Vrstevnica	125
CA030 Výšková kóta	126
AL019 Zakryté skladiško	127
DB070 Zárez	128
AN010 Železnica	129
AQ063 Železničné priecestie	131
EA020 Živý plot, stromoradie	132

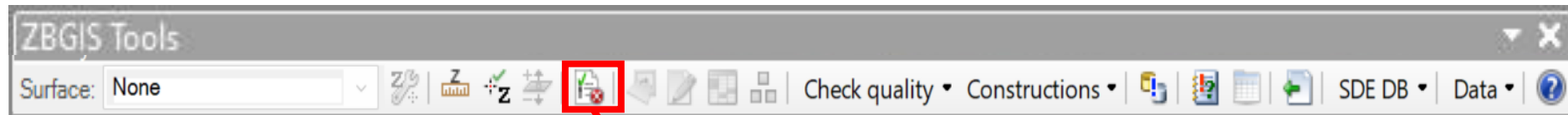


Time accuracy

- Checking the value of the DOW (Object update date) attribute.

Logical consistency

- Domain and Topological consistency is defined by ZBGIS Feature Catalogue.
- Control method – these sub-elements of the quantitative side of quality are checked automatically by the tools of the spatial geodatabase management system or by our custom-made tools (ZBGIS TOOLS). Used software - ArcGIS (ESRI). It is implemented on the entire controlled area.



Validation of Z coordinate values.

ZBGIS – 1st phase of quality check



Validation - of topological, attribute and procedural rules

Validation

Categories Rules Validation result

Import

Predefined XML

C:\Program Files (x86)\Zymestic Solutions\ZBGIS Nástroje 23.32

cesta

- Cesta - Overenie atribútu TXT ak EXS=999
- Cesta - Overenie atribútu SOI ak EXS=0
- Cesta - Vyplnenie atribútu FACC
- Cesta - Vyplnenie atribútu EXS
- Cesta - Vyplnenie atribútu RDT
- Cesta - Overenie atribútu TXT ak RDT=999
- Brod, priepust, hať (plocha) - križovanie cesty a vodného toku
- Brod, priepust, hať (plocha) - križovanie chodníka a vodného toku
- Cesta - Vyplnenie atribútu LOC
- Cesta - Vyplnenie atribútu LOC v závislosti c
- Cesta - Overenie atribútu TXT ak LOC=999
- Cesta - Vyplnenie atribútu SMC v závislosti i
- Cesta - Vyplnenie atribútu SMC
- Cesta - Overenie atribútu SOI ak SMC=0
- Cesta - Overenie atribútu TXT ak SMC=999
- Cesta - Vyplnenie atribútu RTN v závislosti c
- Cesta - Vyplnenie atribútu RTN
- Cesta - Overenie atribútu RST
- Cesta - Vyplnenie atribútu WD2
- Cesta - Vyplnenie atribútu WD2 v závislosti i
- Cesta - Vyplnenie atribútu NAM
- Cesta - Vyplnenie atribútu ID_SSC
- Cesta - Vyplnenie atribútu GN_ID_NAM
- Cesta - Vyplnenie atribútu GN_ID_RTN
- Cesta - Vyplnenie atribútu OHC
- Cesta - Overenie atribútu TXT ak RST=999
- Cesta - Overenie dĺžky
- Cesta - Vyplnenie atribútu TXT v závislosti o
- Cesta - Overenie atribútu SOI ak WD2=327
- Cesta - Overenie atribútu GN_ID_RTN
- Cesta na moste
- Cesta v budove/ostatné objekty plocha
- Brána na ceste
- Rozdelenie cesty na moste
- Poloha ciest na moste

Validation

Categories Rules Validation result

Attributes rule Procedural rules Topologies rules

Rules

Rule name	Geometry	Source class	Query over source class	Source attribute	Rule type	Target class	Query over target class
Brána - križovanie cesty a plotu	Line	cesta			ProceduralRule_LineCrossesLineSegmentMustContainPoint	plot	
Brána - križovanie chodníka a plotu	Line	chodnik			ProceduralRule_LineCrossesGeometryMustContainGeom...	plot	
Brána - križovanie železnice a plotu	Line	zeleznica			ProceduralRule_LineCrossesLineSegmentMustContainPoint	plot	
Brána bez komunikácie	Point	brana	TXT <> 'bez komunikácie'		ProceduralRule_Intersect	cesta;chodnik;zeleznica	
Brána na ceste	Line	cesta			ProceduralRule_MustIntersectEndPointQueryAttribute	brana	
Brána na železnici	Line	zeleznica			ProceduralRule_MustIntersectEndPointQueryAttribute	brana	
Brod, priepust, hať (plocha) - križovanie cesty a vodného toku	Line	cesta	LOC <> 300		ProceduralRule_LineCrossesGeometryMustContainGeom...	vodny_tok	EXS <> 214 AND LOC <> 7
Brod, priepust, hať (plocha) - križovanie chodníka a vodného toku	Line	chodnik	LOC <> 300		ProceduralRule_LineCrossesGeometryMustContainGeom...	vodny_tok	EXS <> 214 AND LOC <> 7
Budova v omeje pôde	Area	budova	BFC <> 20		ProceduralRule_AreaMustNotContainGeometry	oma_poda	
Cesta na moste	Line	cesta	LOC NOT IN (300, 301, 302)		ProceduralRule_LineNotWithinArea	most	
Cesta na parkovisku	Area	parkovisko			ProceduralRule_LineTouchBorderArea	cesta	
Cesta v budove/ostatné objekty plocha	Line	cesta			ProceduralRule_LineWithinAreaQueryAttribute	budova;ostatne_obj_p	:OBJ=21
Cesta v záhradkovej osade	Line	cesta			ProceduralRule_LineInAreaQueryAttribute	ovocny_sad	VEG=314
Dĺžka krytého vodného toku	Line	vodny_tok	LOC=7		ProceduralRule_LineLengthGreatThan		
Elektrické vedenie v lese	Line	el_vedenie			ProceduralRule_NotCross	les	
Hať (línia) sa musí križovať s vodným tokom	Line	hat_l			ProceduralRule_Intersect	vodny_tok	
Hať (plocha) - križovanie cesty a vodnej plochy, plochy vodného toku.	Line	cesta	LOC <> 300 AND LOC <> 304		ProceduralRule_LineCrossesGeometryMustContainGeom...	vodny_tok_plocha; vodna_plocha	
Hať (plocha) - križovanie chodníka a vodnej plochy, plochy vodného toku.	Line	chodnik	LOC <> 300 AND LOC <> 304		ProceduralRule_LineCrossesGeometryMustContainGeom...	vodny_tok_plocha; vodna_plocha	
Hať (plocha) sa musí križovať s vodným tokom	Area	hat_p			ProceduralRule_Intersect	vodny_tok	
Chodník na moste	Line	chodnik	LOC NOT IN (300, 301, 302)		ProceduralRule_LineNotWithinArea	most	
Chodník v budove/ostatné objekty plocha	Line	chodnik			ProceduralRule_LineWithinAreaQueryAttribute	budova;ostatne_obj_p	:OBJ=21
Chýba bodová atrakcia.	Area	ostatne_obj_p	OBJ=19		ProceduralRule_AreaMustContainGeometry	atrakcia	
Chýba bodová fontána.	Area	ostatne_obj_p	OBJ=24		ProceduralRule_AreaMustContainGeometry	fontana	
Chýba bodový pomník.	Area	ostatne_obj_p	OBJ=25		ProceduralRule_AreaMustContainGeometry	pomnik	
Komunikácia na moste	Area	most			ProceduralRule_AreaMustContainGeometry	cesta;zeleznica;chodnik	
Križ na cintoríne	Point	kriz			ProceduralRule_NotIntersect	zelen	USE=300
Križovanie cesty s cestou na moste	Line	cesta			ProceduralRule_LineCrossLineWithinArea	cesta	
Križovanie elektrického vedenia.	Line	el_vedenie	<>NAP	NAP	ProceduralRule_CrossNotCommonVertex		
Materiálové zloženie el. stĺpu	Point	stp_el_vedenia	MCC IN (117, 83)		ProceduralRule_NotIntersect	el_vedenie	NAP IN (302, 303, 304)

Close

Remove selected categories

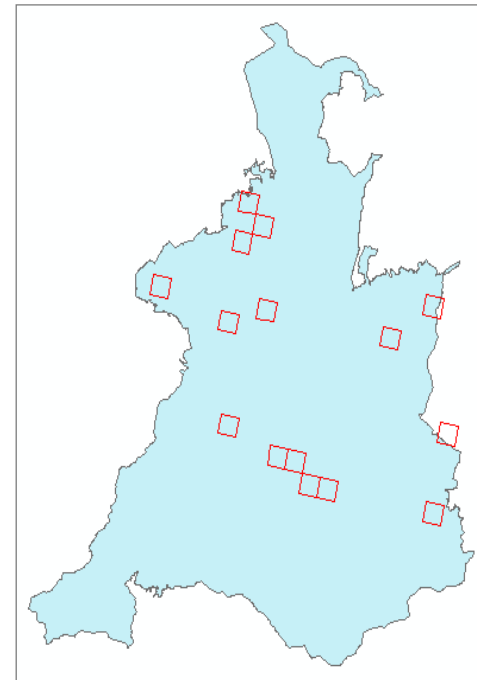
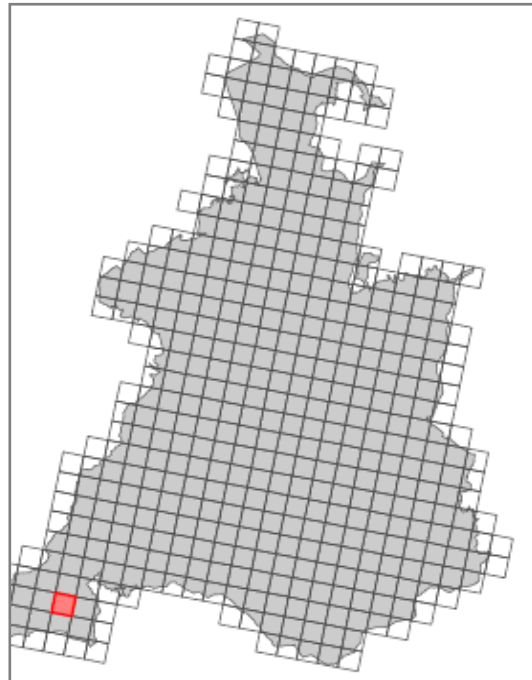
Start validation

Close



Control method for 2nd phase

- Positional and thematic accuracy check.
- Comparison of data from local quality control investigation in the field with ZBGIS data.
- Controlled locality divided by regular spatial grid, where control cells are selected randomly.
 - Selection of the number of cells from control grid - for the area of 200 km² will be selected 10 cells (1x1 km), which represents 5% of the territory.
- At least 95% of the spatial objects from each feature class in the checked locality must meet the quality requirements.





Thematic accuracy

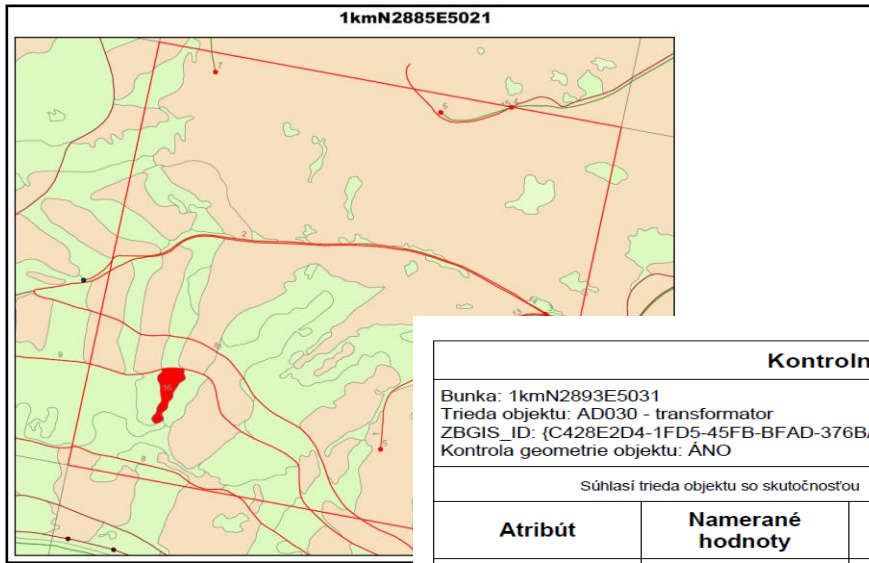
- correctness of object classification - according to ZBGIS Feature Catalogue
- correctness of non-quantitative attributes - according to ZBGIS Feature Catalogue
- accuracy of quantitative attributes

HGT(height) \geq 7m	\pm 2 m
HGT(height) (7 - 30> m	\pm 3 m
HGT(height) (30 - 50> m	\pm 4 m
HGT(height) (50 -100> m	\pm 5 m
HGT(height) > 100 m	\pm 6 m
Acceptance of the number of errors above the allowed limits at the HGT value for Buildings is maximum of 2.5%, for other classes of objects is maximum of 5%.	
WD2(width)	\pm 10 % of real value
Acceptance of errors above the permitted limits at the WD2 value of a maximum of 5%.	
LOB(length) \leq 10 m	\pm 1 m
LOB(length) > 10 m	\pm 10 % of real value
Acceptance of errors above the permitted limits at the LOB value is maximum of 5%.	

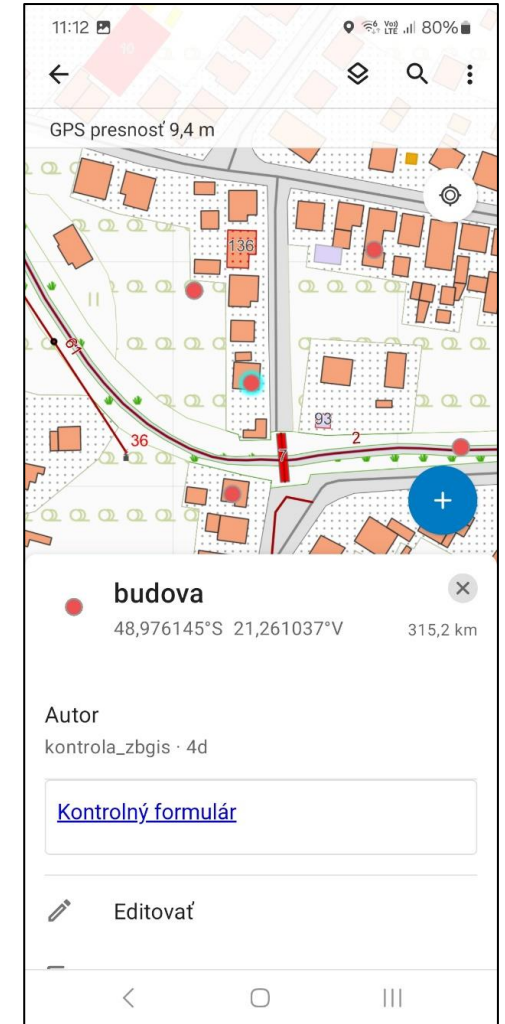


Thematic accuracy

- Control method - investigation of thematic accuracy directly in the field → completion of control sheets (printed or digital form) and control geodatabase.



Kontrolný list			
Bunka: 1kmN2893E5031		Kontrolovaný objekt číslo: 1	
Trieda objektu: AD030 - transformator			
ZBGIS_ID: {C428E2D4-1FD5-45FB-BFAD-376BA9BA787B}			
Kontrola geometrie objektu: ÁNO			
Súhlasí trieda objektu so skutočnosťou		ÁNO <input type="checkbox"/>	NIE <input type="checkbox"/>
Atribút	Namerané hodnoty	Spôsob získania a použité prístroje a pomôcky	
HGT	Výška nad povrchom		
Iné zistenia/opis objektu:			
	Meno a priezvisko	Dátum	Podpis
Šetriť v teréne:			





Positional accuracy

- The positional accuracy of ZBGIS is not tested by direct geodetic measurement in the field - only the correctness check is carried out over the available orthophotomosaic and DTM/DSM and check of the ACH (horizontal accuracy) and ACV (vertical accuracy) attributes completion for newly created objects.



Thank you for your attention