# MAPPINGMATTERS

## YOUR QUESTIONS ANSWERED

*The layman's perspective on technical theory and practical applications of mapping and GIS*

BY Qassim A. Abdullah, Ph.D., PLS, CP**

## QUESTION:

Q: I am evaluating a lidar-based surface model and collecting checkpoints in each land category as follows:

| Land Category | Number of Checkpoints |
|---|---|
| Bare Earth | 21 |
| Low Vegetation | 30 |
| Medium Vegetation | 20 |
| High Vegetation | 20 |
| Urban | 21 |
| Total | 112 |

The surface model needs to meet an accuracy suitable for the generation of 2-foot contour interval. After field checking the vertical fit of 112 checkpoints, I found the differences are ranging from -0.985 to 0.525 feet with an RMSE value of 0.290 feet. Please see details in the tables below. As an ASPRS member, I attended many of your presentations over the years and would appreciate your insight on the following questions.

1) What statement can be made about the RMSE value of 0.290 feet?

2) Considering the deliverable data was for a contour interval of 2 feet, what are the qualifying statements for vegetated and non-vegetated terrain accuracy?

3) For the classes of vegetated and non-vegetated terrain, what number in my results is compared to the ASPRS report to make these qualifying statements?

Victor Murray, ASPRS Member, Ada, Oklahoma

| All Categories | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 112 | 112 |
| Mean | -0.037 | 0.223 |
| Median | 0.021 | 0.172 |
| Minimum | -0.985 | 0.000 |
| Maximum | 0.525 | 0.985 |
| STD DEV | 0.289 | 0.186 |
| RMSEz | 0.290 | 0.290 |

| Bare Earth | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 21 | 21 |
| Mean | 0.108 | 0.158 |
| Median | 0.093 | 0.143 |
| Minimum | -0.210 | 0.014 |
| Maximum | 0.525 | 0.525 |
| STD DEV | 0.180 | 0.135 |

| VEG LOW | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 30 | 30 |
| Mean | 0.010 | 0.191 |
| Median | 0.009 | 0.164 |
| Minimum | -0.608 | 0.010 |
| Maximum | 0.426 | 0.608 |
| STD DEV | 0.235 | 0.132 |

| VEG MED | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 20 | 20 |
| Mean | -0.260 | 0.343 |
| Median | -0.302 | 0.322 |
| Minimum | -0.648 | 0.023 |
| Maximum | 0.335 | 0.648 |
| STD DEV | 0.307 | 0.205 |

| VEG HIGH | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 20 | 20 |
| Mean | -0.136 | 0.277 |
| Median | -0.017 | 0.190 |
| Minimum | -0.985 | 0.000 |
| Maximum | 0.384 | 0.985 |
| STD DEV | 0.365 | 0.268 |

| URBAN PAVED | Real (ft) | ABS (ft) |
|---|---|---|
| Count | 21 | 21 |
| Mean | 0.061 | 0.170 |
| Median | 0.092 | 0.117 |
| Minimum | -0.342 | 0.015 |
| Maximum | 0.481 | 0.481 |
| STD DEV | 0.203 | 0.122 |

**Dr. Abdullah:** Looking at the accuracy requirements of the final product, it is clear that the project laps two eras of map accuracy standards, the old ASPRS standards of 1993 and the new ASPRS Positional Accuracy Standards for Digital Geospatial Data. This was obvious when Victor stated, "The surface model needs to meet accuracy suitable for the generation of 2-foot contour interval." I called this era "the transition period," as users of the new standard are trying to bridge the gaps and minimize confusions between the old and new standards. Predicting such behavior was a top priority for the drafting committee during the design and authorization of the new standard. We expected that users would eventually need guidelines during such transition period. Rightfully so, we provided a wealth of examples and tables to relate the new standard to the legacy ones. Looking into Victor's question, I noticed the following:

1. **The Stated Accuracy Requirement**: Specifying that product accuracy should meet 2-foot contours does not align with the spirit of the new standard, as the new standard

Photogrammetric Engineering & Remote Sensing
Vol. 82, No. 4, April 2016, pp. 243–248.
0099-1112/16/243–248

doi: 10.14358/PERS.82.4.243

does not endorse the association of imagery scale, ground sampling distance (GSD) or contour interval (CI) with the final accuracy of the geospatial products. The new standard defines product's accuracy in terms of the expected root mean square error (RMSE) of that product. For Victor's project, the vertical accuracy needs to be stated as "15-cm class," "20-cm class," etc., where 15-cm accuracy class means the vertical accuracy of the product should be within $RMSE_z$ = 15 cm. To mitigate this issue, we would have to offer a hybrid approach during this transition period. By "hybrid approach," I mean condoning the 2-foot contour vertical accuracy requirement as used by the legacy ASPRS standard to derive a figure that is suitable for reporting the accuracy according to the new standards. According to the legacy ASPRS standard, the vertical accuracy for 2-foot contours products is $RMSE_z$ = 1/3rd of the CI, or about 20 cm. Therefore, we can state that the digital surface model for this project needs to meet a vertical accuracy class of 20-cm according to the new ASPRS Positional Accuracy Standards for Digital Geospatial Data.

2. **The Tested Land Categories**: The previous tables specify five land cover categories. Those are "Bare Earth," "Low Vegetation," "Medium Vegetation," "High Vegetation," and "Urban." The new standard classifies the terrain into only two categories: "Vegetated," which represents open terrain and "Non-vegetated," which represents the part of the terrain where the ground is obscured by vegetation. Therefore, according to the new standard, we need to consolidate similar categories to form the two categories. All the checkpoints located within the categories "Low Vegetation," "Medium Vegetation," and "High Vegetation" need to be combined to form the "Vegetated" category, and points located within the categories "Bare Earth" and "Urban" need to be combined together to form the "Non-vegetated" category. The results of checkpoints within the "Non-vegetated" category represent the "Non-vegetated Vertical Accuracy (NVA)" according to the new standards, while checkpoints from the "Vegetated" category determine the "Vegetated Vertical Accuracy (VVA)". Accordingly, the NVA needs to meet a vertical accuracy class of 20 cm. However, there is no VVA accuracy figure that can be derived from the project specifications, as the old standard only specifies accuracy for bare earth. According to the old practices and ASPRS legacy standard, vegetated areas used to be represented with dashed contour lines to indicate non-guaranteed or lower accuracy areas. Luckily, the new standard in Table 7.2 specifies the VVA to be equal to ≤3.00 * vertical accuracy class. Accordingly, the VVA for this project is ≤ 60-cm as 95th percentile.

**"Specifying that product accuracy should meet 2-foot contours does not align with the spirit of the new standard"**

3. **The Measurement Units**: The new ASPRS Positional Accuracy Standards for Digital Geospatial Data is based on the metric system. Therefore, converting all the values in Victor's tables to meters and centimeters as the new standard suggests is advisable.

Now that all the observations on the data are presented, here is what Victor needs to do to state the product accuracy according to the ASPRS Positional Accuracy Standards for Digital Geospatial Data:

**Computing NVA**:

- Consolidate the 21 checkpoints located in "Bare Earth" areas and the 21 checkpoints located in the "Urban" areas into one table to represent the NVA.
- Recalculate the statistics for the differences in the 42 checkpoints as illustrated in the following table:

| NVA | (ft) | (centimeter) |
|---|---|---|
| Count | 42 | 42 |
| Mean | 0.084 | 2.57 |
| Median | 0.093 | 2.82 |
| Minimum | -0.342 | -10.42 |
| Maximum | 0.525 | 16.00 |
| STD DEV | 0.191 | 5.82 |
| RMSEz | 0.207 | 6.30 |
| NVA (1.96 x RMSEz) | 0.405 | 12.35 |

Or simply,

| NVA | (centimeter) |
|---|---|
| Count | 42 |
| Mean | 2.57 |
| STD DEV | 5.82 |
| RMSEz | 6.30 |
| NVA (1.96 x RMSEz) | 12.35 |

As you may have noticed, I eliminated any reference in the last table to the foot/inch units and kept only the metric units. I also removed some statistical terms such as MIN and MAX, as they are not relevant to the final reporting. However, they may come handy during the results analysis stage. I kept the mean and standard deviation values in the table to compare it to the computed $RMSE_z$ value. Evaluating the mean and the standard deviation and comparing it to the calculated $RMSE_z$ value may help discover biases in the results. To calculate the $RMSE_z$ and the NVA follow the following instructions, Annex D of the new ASPRS standard provides step-by-step instructions and numerical examples on computing all the statistical terms that I previously mentioned:

1. Compute the differences between the surveyed elevation and the lidar-derived elevation for all the check points located in open ground:

$$Difference = (Z_{i(map)} - Z_{i(surveyed)})$$

The following Table is a sample on calculating the differences or the residuals in the elevation fit:

| Point ID | Northing | Easting | Surveyed H | Lidar H | Difference (ft) | Difference (cm) |
|---|---|---|---|---|---|---|
| PT-1 | 248625.003 | 2099927.620 | 1101.788 | 1101.319 | -0.47 | -14.30 |
| PT-2 | 106224.367 | 2111913.255 | 1189.472 | 1189.538 | 0.07 | 2.01 |
| PT-3 | 196036.487 | 2168118.736 | 1216.597 | 1216.350 | -0.25 | -7.53 |
| PT-4 | 207652.511 | 2117099.375 | 1182.528 | 1182.496 | -0.03 | -0.98 |
| … | ….. | ….. | …. | ….. | …. | …. |

2. Compute the $RMSE_z$ using the following formula:

$$RMSE_Z = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_{i(map)} - Z_{i(surveyed)})^2}$$

Where,

$Z_{i(map)}$ is the elevation of the $i^{th}$ checkpoint in the data set,

$Z_{i(surveyed)}$ is the elevation of the $i^{th}$ checkpoint in the independent source of higher accuracy,

$n$ is the number of checkpoints tested,

$i$ is an integer ranging from 1 to $n$.

**"Users of the new ASPRS Positional Accuracy Standards for Digital Geospatial Data are encouraged to start defining the accuracy of the final deliverables in terms of RMSE (i.e. x-cm) and to stay away from expressing the product accuracy in terms of map scale and contour interval"**

3. Compute the NVA using the following formula:

*Vertical Accuracy at 95% Confidence Level = 1.96 x* ($RMSE_Z$)

**Computing VVA**:

a. Consolidate the 30 checkpoints located in the "Low Vegetation" area, the 20 checkpoints located in the "Medium Vegetation" area and the 20 checkpoints located in the "High Vegetation" area into one table to represent the VVA.

b. Recalculate the statistics for the differences in the 70 checkpoints located in the vegetated areas as illustrated in the following table:

| VVA | (ft) | (centimeter) |
|---|---|---|
| Count | 70 | 70 |
| Mean | -0.109 | -3.33 |
| Median | -0.082 | -2.48 |
| Minimum | -0.985 | -30.02 |
| Maximum | 0.426 | 12.98 |
| STD DEV | 0.314 | 9.58 |
| RMSEz | 0.331 | 10.08 |
| VVA 95th Percentile | 0.348 | 10.61 |

Or simply,

| VVA | (centimeter) |
|---|---|
| Count | 70 |
| Mean | -3.33 |
| STD DEV | 9.58 |
| RMSEz | 10.08 |
| VVA 95th Percentile | 10.61 |

Due to the combined effects of the questionable quality and inconsistency in the surveying practices under and between trees, especially if the survey relies on GPS techniques and the reliability of the lidar filtering process around vegetated areas, $RMSE_z$ cannot be used to estimate VVA. $RMSE_z$ only should be used to estimate the accuracy of a data sample if the error is normally distributed. Unfortunately, errors estimated around vegetated areas may be skewed due to the two reasons mentioned earlier concerning the reliability of the survey and the lidar data filtering process. That was the reason behind the use of "95% percentile" to represent the VVA in the new standard. To compute the VVA follow the following instructions:

1. Compute the differences between the surveyed elevation and the lidar-derived elevation for all the checkpoints located in vegetated areas as we did for the NVA computations.

2. Compute the VVA using the $95^{th}$ percentile for the 70 elevation differences of the checkpoints located within the vegetated areas. The easiest way to do this is by using the following formula from Microsoft Excel:

*The $95^{th}$ percentile =PERCENTILE($G_i$:$G_{i+70}$,0.95)*

**Reporting NVA and VVA according to the ASPRS Positional Accuracy Standards for Digital Geospatial Data**:

The new standard provided clear guidelines and statements to report products accuracy. According to such guidelines, the reported accuracy for Vicotr's product can be expressed as follow:

*"This data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 20-cm $RMSE_z$ Vertical Accuracy Class (the derived VVA limit is 60 cm). Actual NVA accuracy was found*

*continued on page 248*

The relative importance of these issues for any professional will vary depending upon their position, the organization that they work for and their "customers." Geospatial professionals, however, will at the very least need to consider the legal issues to make sure there are no "red flags".

Ideally, organizations should be able to rely upon their legal counsel to help them identify and resolve key legal issues. However, the legal and policy communities have been unable to keep pace with the growth of geospatial technology and the rapid adoption of applications that utilize geospatial information. Spatial Law is not taught in law school and the Centre for Spatial Law and Policy, in partnership with the United States Geospatial Intelligence Foundation (USGIF), are the only organizations offering courses that provide Continuing Legal Education (CLE) credits for lawyers. As a result, many organizations do not have lawyers well versed in these issues. Therefore, it will be incumbent upon geospatial professionals in the near term to have a working knowledge of the legal issues associated with geospatial information to identify the salient issues and bring them to their lawyer's attention.

The geospatial community can take several steps to address this shortfall. Spatial Law can be incorporated into undergraduate and graduate curriculum in geospatial-related fields. In addition, geospatial professional training and certification programs should include segments that address key legal issues. Organizations should also help their lawyers in learning more about geospatial technology and ways in which geospatial information is being used and encourage them to attend specific training, such as geospatial focused CLEs.

**Kevin D. Pomfret, Esq**. is the founder and Executive Director of the Centre for Spatial Law and Policy and a Partner at Williams Mullen.

**Mapping Matters**
*continued from page 245*

**"Due to the combined effects of the questionable quality and inconsistency in the surveying practices under and between trees, especially if the survey relies on GPS techniques and the reliability of the lidar filtering process around vegetated areas, RMSEz cannot be used to estimate VVA."**

*to be $RMSE_z$ = 6.3 cm, equating to +/- 12.3 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 10.6 cm at the $95^{th}$ percentile."*

Based on the previous reported accuracy, the product accuracy is well within the accuracy limits of NVA = 20 cm and VVA = 60 cm and met both the NVA and the VVA requirements according to the new ASPRS Positional Accuracy Standards for Digital Geospatial Data. In fact, such product is eligible for the following accuracy statement:

*"This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class equating to NVA =+/- 19.6 cm at 95% confidence level and VVA =+/- 30 cm at the 95th percentile. Actual NVA accuracy was found to be $RMSE_z$ = 6.3 cm, equating to +/- 12.3 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 10.6 cm at the $95^{th}$ percentile."*

Users of the new ASPRS Positional Accuracy Standards for Digital Geospatial Data are encouraged to start defining the accuracy of the final deliverables in terms of RMSE (i.e. *x-cm*) and to stay away from expressing the product accuracy in terms of map scale and contour interval. They are also encouraged to use metric units when defining product accuracy as the new standard is based on the metric system.

***Dr. Abdullah is Senior Geospatial Scientist and Associate at Woolpert, Inc. He is the 2010 recipient of the ASPRS Photogrammetric (Fairchild) Award.*

**The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or Woolpert, Inc.**