NSDI

National Spatial Data Infrastructure

Draft Geospatial Positioning Accuracy Standards
Part 3: National Standard for Spatial Data Accuracy

Subcommittee for Base Cartographic Data
Federal Geographic Data Committee

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CONTENTS

3.1 INTRODUCTION

3.1.1 Purpose

The National Standard for Spatial Data Accuracy (NSSDA) implements a well-defined statistic and testing methodology for positional accuracy of spatial data, in both digital and graphic forms, derived from sources such as aerial photographs, satellite imagery, and maps. It provides a common language to report accuracy to facilitate the identification of spatial data for geographic applications.

This standard does not define "pass-fail" accuracy values. Agencies are encouraged to establish "pass-fail" criteria (for example, using values specified in other positional accuracy standards) for their product specifications and applications and for contracting purposes. Ultimately, users must identify acceptable accuracies for their applications. Data and map producers must determine what accuracy exists or is achievable for their data and report it according to NSSDA.

This standard is classified as a **Data Useability Standard** by the Federal Geographic Data Committee (FGDC) Standards Reference Model. A Data Useability Standard describes how to express "the applicability or essence of a data set or data element" and includes "data quality, assessment, accuracy, and reporting or documentation standards."

This standard replaces the United States National Map Accuracy Standards (U.S. Bureau of the Budget, 1947).

3.1.2 Applicability

Use the NSSDA to determine and report the positional accuracy of spatial data produced, revised, or disseminated by or for the Federal Government.

3.1.3 Maintenance

The U.S. Department of the Interior, U.S. Geological Survey (USGS), National Mapping Division, maintains the National Standard for Spatial Data Accuracy (NSSDA) for the Federal Geographic Data Committee. Address questions concerning the NSSDA to: Chief, National Mapping Division, USGS, 516 National Center, Reston, VA 22092.

3.1.4 Standards Development Procedures

The National Standard for Spatial Data Accuracy was developed by the FGDC *ad hoc* working group on spatial data accuracy to replace the United States National Map Accuracy Standards (NMAS). The American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps formed the basis for revision of the NMAS (ASPRS Specifications and Standards Committee, 1990). The NSSDA, in its former version as the draft National Cartographic Standards for Spatial Accuracy (NCSSA), extended the ASPRS Accuracy Standards to map scales smaller than 1:20,000. The NCSSA were released for public review through the Federal Geographic Data Committee and were substantially rewritten as a result. Principal changes included omission of a defined accuracy specification in favor of a requirement for reporting tested or expected accuracy; a composite statistic for horizontal accuracy instead of component (x,y) accuracy, and alignment with emerging FGCS accuracy standards (FGCS, 1995). The NCSSA was renamed the National Standard for Spatial Data Accuracy to emphasize its applicability to digital spatial data as well as graphic maps.

3.1.5 Relationship to Federal Geodetic Control Subcommittee Standards

The positional accuracy of points derived from geodetic surveying is reported according to draft Standards for Geodetic Control Networks (Federal Geodetic Control Subcommittee, 1996). Accuracy classifications for geodetic control networks are tabulated in Appendix A, Section A.4, Check Survey Design, of the NSSDA. Ground coordinates of points according to Federal Geodetic Control Subcommittee standards are used in the National Spatial Reference System (NSRS) unified multidimensional national control network. NSRS ground control may be used to reference spatial data, including project control surveys, to a common georeference system. The accuracy of spatial data derived from control surveys is expressed using the NSSDA.

The NSSDA may also be related to the FGCS standard by using NSRS points as check points to test accuracy of spatial data derived from aerial photographs, satellite imagery, maps, and other secondary sources.

3.2 TESTING METHODOLOGY AND REPORTING REQUIREMENTS

3.2.1 Spatial Accuracy

Horizontal spatial accuracy is defined by circular error of a data set's horizontal coordinates at the 95% confidence level.[1] Vertical spatial accuracy is defined by linear error of a data set's vertical coordinates at the 95% confidence level.[2]

Accuracy reported at the 95% confidence level means that 95% of positional accuracies will be equal to or smaller than the reported accuracy value. The reported accuracy value is the cumulative result of all uncertainties, including those introduced by geodetic control coordinates, compilation, and final extraction of ground coordinate values in the spatial data.

3.2.2 Multiple Accuracies

Spatial data may be compiled to comply with one level of accuracy in the vertical component and another in the horizontal components.

A data set may contain themes or geographic areas that have different accuracies. Report multiple accuracies in the same spatial data set if information exists that relates accuracy to individual portions of the data set.

3.2.3 Accuracy Test

The producer of the spatial data will determine the geographic extent of data to be tested and the amount of testing.

Test horizontal accuracy by comparing the planimetric coordinates of well-defined ground points[3] with coordinates of the same points from an independent source of higher accuracy. Select the check source so that its accuracy is within one-third the accuracy of the data set at the 95% confidence level.[4]

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1 see Appendix A, section 1

2 see Appendix A, section 2

3 see Appendix A, section 3

4 see Appendix A, section 4

Test vertical accuracy by comparing the elevations of well-defined points with elevations of the same points as determined from a source of higher accuracy. When checking elevations, the horizontal position of the ground point may be shifted in any direction by an amount no more than twice its expected accuracy at the 95% confidence level. Select the check source so that accuracies at check point locations are within one-third the data set's accuracy at the 95% confidence level.

Errors two times or more than that allowed for the intended accuracy at the 95% confidence level are blunders and must be corrected. After blunders are corrected, redetermine accuracies at test points.

Test a minimum of 20 check points, distributed to reflect the geographic extent and the distribution of error in the data set.[5] Document the number of check points and their coordinates.

3.2.4 Accuracy Reporting

Report accuracy of spatial data evaluated by the NSSDA in ground units. Metric units are used when the data set coordinates are in meters. Feet are used when the data set coordinates are in feet.

If data of varying accuracies can be identified separately in a data set, compute and report separate accuracy values. If data of varying accuracies are composited and cannot be separately identified AND the data set is tested, report the accuracy value for the composited data. If a composited data set is not tested, report the accuracy value for the least accurate data set component.

[5] see Appendix A, section 5

Include the information shown below in spatial data and on maps.

Report accuracy at the 95% confidence level for data *tested* for both horizontal and vertical accuracy as:

Tested ____ meters/feet accuracy (horizontal) at 95% confidence level
____ meters/feet accuracy (vertical) at 95% confidence level

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Report accuracy at the 95% confidence level for data *produced according to established procedures* to comply with intended horizontal and vertical accuracy values as:

Compiled to meet ____ meters/feet accuracy (horizontal) at 95% confidence level
____ meters/feet accuracy (vertical) at 95% confidence level

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Report accuracy for data *tested* for horizontal accuracy and *produced according to established procedures* to comply with an intended vertical accuracy value as:

Tested ____ meters/feet accuracy (horizontal) at 95% confidence level
Compiled to meet ____ meters/feet accuracy (vertical) at 95% confidence level

National Standard for Spatial Data Accuracy 1995

Show similar labels when data are *tested* for vertical accuracy and *produced according to established procedures* to comply with an expected horizontal accuracy value.

If a data set does not contain vertical information, label for horizontal accuracy information only.

3.3 NSSDA AND OTHER MAP ACCURACY STANDARDS

Accuracy of new or revised spatial data will be reported by NSSDA. Accuracy of existing or legacy spatial data and maps may be reported by NSSDA or by the accuracy standard by which they were evaluated. Appendix B describes root mean square error (RMSE), former NMAS, and ASPRS Accuracy Standards for Large-Scale Maps. These standards, their relationships to NSSDA, and accuracy labeling are described to ensure that users have some means to assess positional accuracy of spatial data or maps for their applications.

If accuracy reporting cannot be provided using NSSDA or other recognized standards, provide useful information to enable users to evaluate how the data fit their applications requirements. This information may include descriptions of the source material from which the data were compiled, accuracy of ground surveys associated with compilation, digitizing procedures, equipment, and quality control procedures used in production.

NORMATIVE REFERENCES

Federal Geographic Data Committee, 1996, Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards *(draft)*: Washington, D.C., Federal Geographic Data Committee, 7 p.

BIBILIOGRAPHIC REFERENCES

American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990, ASPRS Accuracy Standards for Large-Scale Maps: Photogrammetric Engineering and Remote Sensing, v. 56, no. 7, p. 1068-1070.

Federal Geodetic Control Committee, 1984, Standards and Specifications for Geodetic Control Networks: Silver Spring, Md., National Geodetic Survey, National Oceanic and Atmospheric Administration, 29 p.

Federal Geodetic Control Subcommittee, 1996, Part 2, Standards for Geodetic Networks, Geospatial Positioning Accuracy Standards *(draft)*: Silver Spring, Md., Federal Geodetic Control Subcommittee, 8 p.

Federal Geographic Data Committee, 1994, Content Standards for Digital Geospatial Metadata: Washington, D.C., Federal Geographic Data Committee, 66 p.

U.S. Bureau of the Budget, 1947, United States National Map Accuracy Standards: U.S. Bureau of the Budget, Washington, D.C.

Appendix 3-A. Explanatory Comments

EXPLANATORY COMMENTS

1. Horizontal Accuracy

Circular error is based on the sample standard deviation of d_i, the difference between the data set coordinate value and the coordinate value determined by an independent check survey of higher accuracy for the same point. The standard deviation for the horizontal coordinate r is:

$$sigma_r = sqrt[\sum(d_i - d)^2/(n-1)]$$

where:

$d_i =$ $r_{data\ I} - r_{check\ I}$
$r_i =$ $sqrt(x_i^2 + y_i^2)$
$d =$ $\sum d_i/n$, the mean discrepancy
$n =$ total number of points checked

NSSDA horizontal accuracy is:

$Accuracy_r = 2.4477 * sigma_r$, at the 95% confidence level.

Where $sigma_x = sigma_y$ (equal precision and accuracy for x, y components), $sigma_r = sigma_x = sigma_y$.

2. Vertical Accuracy

Linear error is based on sample standard deviation of d_i, the difference between the data set elevation and the elevation determined by an independent check survey of higher accuracy for the same point. The standard deviation for the z coordinate direction is:

$$sigma_z = sqrt[\sum(d_i - d)^2/(n-1)]$$

where:

$d_i =$ $z_{data\ I} - z_{check\ I}$

$d =$ $\sum d_i/n$, the mean discrepancy

$n =$ total number of points checked

NSSDA vertical accuracy is:

$Accuracy_z = 1.96 * sigma_z$, at the 95% confidence level.

3. Well-Defined Points

Well-defined points are features that can be identified within a precision of one-third of the maximum expected uncertainty for the data set. These features should be easily visible or recoverable on the ground. Features not identifiable on the ground within close limits, such as timber lines and soil boundaries, are not useable as test points, even though their positions can be scaled.

The selected features will differ depending on the data source and scale of the product. For small-scale products, acceptable features could include approximate right-angle intersections of roads and railroads; small isolated shrubs or bushes; and corners of structures or buildings. For larger scale products, acceptable features could include centers of utility access covers; intersections of sidewalks with curbs and gutters; and monuments or markers, such as bench marks and property boundary monuments.

4. Check Survey Design

Plan and implement check surveys so that check survey points have accuracies within one-third the intended accuracy for the data set at the 95% confidence level. Although the check survey design information given here is for conventional ground survey methods, other possible sources for higher accuracy information are Global Positioning System (GPS) ground surveys and photogrammetric methods.

Design both horizontal (planimetric) and vertical check surveys based on established positional accuracy standards and field specifications for control surveys (Federal Geodetic Control Subcommittee, 1993, 1995). Compare positional accuracy of the data set with FGCS **network accuracy** reported for the check source. Network accuracy of a control point is the uncertainty of its coordinates with respect to the nearest Continuously Operating Reference Station (CORS) maintained by cooperating Federal and State agencies and managed by the National Geodetic

Survey (NGS), National Oceanic and Atmospheric Administration (NOAA). Horizontal control point accuracy is expressed by the radius of the relative positional error circle at the 95% confidence level. Vertical control point accuracy is expressed by the orthometric height error at the 95% confidence level.

FGCS accuracy at the 95% confidence level is reported in metric units, to the next highest value in 1-, 2-, or 5-unit intervals (Federal Geodetic Control Subcommittee, 1996, p. 2-3):

<u>FGCS Accuracy Classification</u> -95% confidence:

0	reserved for CORS
1-mm	accuracy between 0 and 1-mm
2-mm	accuracy between 0 and 2-mm
5-mm	accuracy between 0 and 5-mm
1-cm	accuracy between 0 and 1-cm
2-cm	etc.
5-cm	
1-dm	
2-dm	
5-dm	
1-m	
2-m	
5-m	
10-m	

5. Check Point Location

Data and/or map producers must determine check point locations. This section provides guidelines for distributing the check point locations.

For a data set covering a rectangular area that is expected to have uniform positional accuracy, check points might be distributed so that points are spaced at intervals of at least 10 percent of the diagonal distance across the data set *and* at least 20 percent of the points are located in each quadrant of the data set.

Check points may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. When data exist for only a portion of the data set, confine test points to that area. When the distribution of error is likely to be nonrandom, it may be desirable to locate check points to correspond to the error distribution.

Appendix 3-B.

Other Accuracy Standards

Appendix B

1. Root-Mean-Square Error (RMSE) Component Accuracy

1.1 Explanation of RMSE Component Accuracy

Spatial accuracy may be defined by the root-mean-square error (RMSE) of x-, y-, or z-coordinate values of sample points at ground scale. RMSE is the square root of the average of the squared differences between data set coordinate values and check survey coordinate values for identical points. The RMSE of each component is determined and reported separately; contrast with the NSSDA, where horizontal accuracy is defined by circular error and not resolved into x and y components. The RMSE is the cumulative result of all uncertainties, including those introduced by the processes of ground control surveys, compilation, and final extraction of ground coordinate values in the spatial data. Computed accuracy applies to tests made on well-defined points only.

1.2 Relationship between NSSDA and RMSE (horizontal)

$\text{RMSE} = \text{sqrt}[\sum d_i^2/n]$

where:

$d_i = x_{\text{data } i} - x_{\text{check } i}$ for the x-direction ***OR***
$d_i = y_{\text{data } i} - y_{\text{check } i}$ for the y-direction
$n =$ total number of points checked

RMSE can be related to the NSSDA horizontal accuracy, assuming equal accuracy and precision in the x and y components, that is, $\text{RMSE}_x = \text{RMSE}_y = \text{RMSE}_r$ (radial). RMSE_r may then be converted to NSSDA horizontal accuracy, Accuracy_r:

$$\text{Accuracy}_r = 2.447 * \text{sqrt}[(n/(n-1))*(\sum(d_i - d)^2/\sum d_i^2)] * \text{RMSE}_r$$

where $d = \sum d_i/n$, i.e., the average of the differences

When the sample size is large, standard deviation and RMSE are nearly equivalent; therefore, $\text{Accuracy}_r \approx 2.447 * \text{RMSE}_r$.

1.3 Relationship between NSSDA and RMSE (vertical)

The RMSE for the z-direction is:

$$\text{RMSE}_z = \text{sqrt}[\sum d_i^2/n]$$

where $d_i = z_{\text{data } i} - z_{\text{check } i}$
n = total number of points checked

RMSE_z may then be converted to NSSDA vertical accuracy, Accuracy_z:

$$\text{Accuracy}_z = 1.96 * \text{sqrt}[(n/(n-1))*(\sum(d_i-d)^2/\sum d_i^2)] * \text{RMSE}_z$$

where $d = \sum d_i/n$, i.e., the average of the differences

When the sample size is large, standard deviation and RMSE are nearly equivalent; therefore, $\text{Accuracy}_z \approx 1.96 * \text{RMSE}_z$.

1.4 RMSE Accuracy Reporting

Label data or maps as described in Section 2.4, "Accuracy Labeling," but substitute "RMSE" for "accuracy (horizontal, vertical) at 95% confidence level."

2. Former National Map Accuracy Standards (NMAS)

2.1 Explanation of NMAS

NMAS specifies that 90% of the well-defined points that are tested must fall within a specified tolerance. For map scales larger than 1:20,000, the NMAS horizontal tolerance is 1/30 inch, measured at publication scale. For map scales of 1:20,000 or smaller, the NMAS horizontal tolerance is 1/50 inch, measured at publication scale. At all map scales, the maximum allowable *vertical* tolerance is one half the contour interval.

2.2 Relationship between NSSDA and NMAS (horizontal)

NMAS (U.S. Bureau of the Budget, 1947) uses a 90% confidence level, rather than the 95% confidence level specified by NSSDA. The circular map accuracy standard (CMAS) is:

$$CMAS = 2.146 * sqrt[\sum(d_i - d)^2/(n-1)], \text{ at the 90\% confidence level}$$

The quantity $sqrt[\sum(d_i - d)^2/(n-1)]$ is a factor in NSSDA horizontal accuracy. Therefore, the CMAS can be converted to NSSDA horizontal accuracy, $Accuracy_r$:

$$Accuracy_r = 2.447/2.146 * CMAS = 1.14 * CMAS.$$

Therefore, NSSDA accuracy is:

(1.14*S/360) feet, for map scales larger than 1:20,000
(1.14*S/600) feet, for map scales of 1:20,000 or smaller

where S is the map scale denominator.

2.3 Relationship between NSSDA and NMAS (vertical)

NMAS (U.S. Bureau of the Budget) uses a 90% confidence level, rather than the 95% confidence level specified by NSSDA. The vertical map accuracy standard (VMAS) is:

$$VMAS = 1.69 * sqrt[\sum(d_i - d)^2/(n-1)]$$

The quantity $sqrt[\sum(d_i - d)^2/(n-1)]$ is a factor in NSSDA vertical accuracy. Therefore, the VMAS can be converted to the NSSDA vertical accuracy statistic, $Accuracy_z$:

$$Accuracy_z = 1.96/1.69 * VMAS = 1.16 * VMAS.$$

Therefore, NSSDA accuracy is (1.16)/2 * CI = 0.58 * CI, where CI is the contour interval.

2.4 NMAS Reporting

Labels refer to NMAS rather than reporting the accuracy value.

Label data, as appropriate:

> These data comply with National Map Accuracy Standards of 1947 for *(horizontal, vertical, horizontal and vertical)* accuracy for 1:_____ scale.

Label maps, as appropriate:

> This map complies with National Map Accuracy Standards of 1947 for *(horizontal, vertical, horizontal and vertical)* accuracy.

3. American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps

3.1 Explanation of ASPRS Accuracy Standards for Large-Scale Maps

ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) provide accuracy tolerances for maps at 1:20,000-scale or larger "prepared for special purposes or engineering applications." RMSE is the statistic used by the ASPRS standards. Accuracy is reported as Class 1, Class 2, or Class 3. Class 1 accuracy for horizontal and vertical components is discussed below. Class 2 accuracy applies to maps compiled within limiting RMSE's twice those allowed for Class 1 maps. Similarly, Class 3 accuracy applies to maps compiled within limiting RMSE's three times those allowed for Class 1 maps.

3.2 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps (horizontal)

Table 1 shows Class 1 planimetric limiting RMSE *in feet* associated with typical map scales.

Table 1

ASPRS Accuracy Standards for Large-Scale Maps

Class 1 planimetric limiting RMSE *in feet* for various map scales

Class 1 Planimetric Accuracy, limiting RMSE (feet)	Map Scale
0.05	1:60
0.1	1:120
0.2	1:240
0.3	1:360
0.4	1:480
0.5	1:600
1.0	1:1,200
2.0	1:2,400
4.0	1:4,800
5.0	1:6,000
8.0	1:9,600
10.0	1:12,000
16.7	1:20,000

Table 2 shows Class 1 planimetric limiting RMSE *in meters* associated with typical map scales.

Table 2

ASPRS Accuracy Standards for Large-Scale Maps

Class 1 planimetric limiting RMSE *in meters* for various map scales

Class 1 Planimetric Accuracy Limiting RMSE (meters)	Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

See Section 1.1 of this appendix on the relationship between NSSDA horizontal accuracy and RMSE.

The ASPRS standard can be converted to NSSDA horizontal accuracy:

$$\text{Accuracy}_r = 2.447 * \text{sqrt}[(n/(n-1))*(\sum(d_i-d)^2/\sum d_i^2)] * \text{RMSE}_r$$

When the sample size is large, $\text{Accuracy}_r \approx 2.447 * \text{RMSE}_r$.

3.3 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps

Vertical map accuracy is defined by the ASPRS Accuracy Standards (ASPRS Specifications and Standards Committee, 1990) as the RMSE in terms of the project's elevation datum for well-defined points only. See Section 1.3 of this appendix on the relationship between NSSDA vertical accuracy and RMSE. The ASPRS vertical accuracy standard can be converted to NSSDA vertical accuracy, $Accuracy_z$

$$Accuracy_z = 1.96 * sqrt[(n/(n-1))*(\sum(d_i-d)^2/\sum d_i^2)] * RMSE_z$$

When the sample size is large, $Accuracy_z \approx 1.96 * RMSE_z$

For Class 1 maps according to the ASPRS Accuracy Standards, the limiting RMSE is set at one-third the contour interval. Spot elevations shall be shown on the map with a limiting RMSE of one-sixth the contour interval or less.

3.4 ASPRS Accuracy Standards for Large-Scale Maps Reporting

Labels refer to the ASPRS Accuracy Standards rather than reporting the accuracy value.

Label maps produced according to this standard:

THIS MAP WAS COMPILED TO MEET THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY

Label maps checked and found to confirm to this standard:

THIS MAP WAS CHECKED AND FOUND TO CONFORM
TO THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY