Commonwealth of Virginia

Model Virginia Map Accuracy Standards Guideline

Virginia Information Technologies Agency (VITA)

Publication Version Control

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Document Version History

Version Information Table		
Version	**Date**	**Purpose of Revision**
OTH701-00	03/15/2009	This is the equivalent of original Base Document that was published by the Council on Information Management in March 1992. It has been upgraded with administrative changes only, including a new document designation to replace the original COV ITRM Guideline 92-1 designation.

Preface

Publication Designation

COV Guideline OTH 701-00: Model Virginia Map Accuracy Standards Guideline.

Subject

Map accuracy standards

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Scheduled Review:

Every two (2) years.

Authority

Code of Virginia, §2.2-2007 (Powers of the CIO)

Code of Virginia, § 2.2-2010 (Additional powers of VITA)

Code of Virginia, §2.2-2458 (Powers and duties of the Board [ITIB])

Scope

This guideline is applicable to all Executive Branch state agencies and institutions of higher education (hereinafter collectively referred to as "agencies") that are responsible for the management, development, purchase and use of information technology resources in the Commonwealth of Virginia.

Purpose

To provide a model approach for defining spatial accuracy as it pertains to maps of all scales greater than or equal to 1:100,000 prepared for special purposes or engineering applications in state agencies. This guideline will:

- Define horizontal and vertical accuracy requirements
- Define map accuracy classes; and
- Define map accuracy testing requirements

General Responsibilities

The Chief Information Officer of the Commonwealth (CIO)

- Directs the formulation and promulgation of ITRM policies, standards, and guidelines

The Virginia Information Technologies Agency (VITA)

- Drafts the IT related policies, standards and guidelines
- Updates the IT related policies, standards and guidelines

The Information Technology Investment Board (ITIB, the Board)

- Approves policies, standards, and guidelines or delegates approval to the CIO

Executive Branch Agencies

- Provide input during the development and the drafting of the IT related policies, standard, and guidelines
- Provide input for the review and updating of IT related policies, standards, and guidelines
- Comply with the requirements established
- Use standards information in planning for the acquisition and modification of information technology resources
- Apply for exceptions when necessary

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SECTION 1

INTRODUCTION

BACKGROUND

The only universally recognized map accuracy standard is the National Map Accuracy Standard. It was adopted in 1941 to aid in the procurement of hardcopy map products by Federal agencies. The National Map Accuracy Standard (NMAS) is generally recognized as not being specific enough to meet the accuracy needs for large scale or local government mapping products. The NMAS may continue to be used for generalized small scale mapping at scales of less than 1:100,000, but a new standard is needed within Virginia to provide detailed accuracy requirements and verification procedures to state, regional and local governing bodies for preparing map specifications for larger scale maps.

The use of digital mapping data throughout the Commonwealth is increasing and the requirement for local, regional and state groups to share such data is especially important as government activities are streamlined and coordinated. This model standard will provide the information needed to guide the collection and labeling of hardcopy and digital map products and will facilitate the exchange of map data by ensuring that maps of the same scale and class developed by different groups are indeed compatible. This model standard will provide:

- a common recognized standard to guide the collection of data for all map scales;
- a common method for verifying and interpreting the data collected and map products produced; and
- a common method of labeling data and map products.

PURPOSE

This model standard is based on the American Society of Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps. It was developed to serve as a common standard that can be used by state, regional and local governing bodies in Virginia to meet their needs for a map accuracy standard.

SECTION 2

MAP ACCURACY STANDARDS

When using the National Map Accuracy Standard, a map either meets the standard or it does not; no specific levels of compliance are specified. This model standard for map accuracy defines the positional accuracy of a hardcopy or digital map product much more fully by incorporating classes of maps. The Class One (1) map designation is used to set the standard and is not easily attained. For map Classes Two (2) and beyond, the average positional error allowed is a multiple of the allowable Class One (1) error and the map class designation number. This use of numerical levels for map accuracy provides several advantages:

- the use of map accuracy class designations will assist map users in determining how appropriate the data is for their particular purposes by giving them more precise positional information; and

- the use of numerical levels of map accuracy provides the capability to request and have map producers deliver higher class maps, thus improving the level of mapping services provided within the Commonwealth.

This model standard defines spatial accuracy as it pertains to maps of all scales greater than or equal to 1:100,000 prepared for special purposes or engineering applications. Emphasis is on the final spatial accuracies that can be derived from the map in terms most generally understood by the users. It should be noted that the accuracy statement pertains to the map at the date of its creation.

The vertical part of the proposed accuracy standard is important in that it allows for the specification of vertical accuracies for maps without contour lines. Digital elevation models and digital terrain models are frequently being used and no mechanism exists for reporting their level of accuracy.

A major feature of this model standard is that it indicates accuracy on the surface of the earth. Thus, digital spatial data of known accuracy can be related to the appropriate map scale for graphic presentation at a recognized standard.

This model standard addresses horizontal and vertical accuracy and defines the test requirements needed to meet various map accuracy classes.

HORIZONTAL ACCURACY

Horizontal map accuracy is defined as the root mean square (rms) error (see Appendix A, Section A1) in terms of the project's planimetric survey coordinates (X,Y) for checked points as determined at full (ground) scale of the map. The rms error is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation and final extraction of ground dimensions from the map. The limiting rms errors established by this standard are the maximum permissible rms errors for 90% of the check points on a map. These limiting rms errors for various classes of maps are tabulated in Tables 1 and 2 along with the map scales typically associated with the limiting errors. These limits of accuracy apply to tests made on well-defined points only (see Appendix A, Section A2).

VERTICAL ACCURACY

Vertical map accuracy is defined as the rms error in elevation in terms of the project's elevation datum for well-defined points only. For Class 1 maps the limiting rms error in elevation is set by the standard at *one-third* the indicated contour interval for well defined points only. Spot heights shall be shown on the map within a limiting rms error of *one-sixth* of the contour interval. The limiting rms error in elevation for spot height data not associated with contours can be determined by consulting Tables 1 and 2. Tables 1 and 2 can also be used as a reporting standard for determining appropriate map scales for various spot height data.

MAP ACCURACY CLASSES

Map accuracies can also be defined at lower spatial accuracy standards. Maps compiled within limiting rms errors of twice or three times those allowed for a Class 1 map shall be designated as Class 2 or Class 3 maps respectively. A map may be compiled that complies with one class for vertical accuracy and another class for horizontal accuracy.

Table 1
Planimetric and Vertical Coordinate Accuracy Requirements in Feet
Ground X or Y or Z for Well-defined Points1

Planimetric Classes (Limiting rms error, feet)					**Vertical Classes** (Limiting rms error, feet)		
CLASS 1	CLASS 2	CLASS 3	Map Scale	Contour Interval in feet	CLASS 1	CLASS 2	CLASS 3
0.0500	0.1000	0.1500	1:60	0.05	0.0083	0.0167	0.0249
0.1000	0.2000	0.3000	1:120	0.10	0.0167	0.0333	0.0501
0.2000	0.4000	0.6000	1:240	0.20	0.0333	0.0667	0.0999
***********	***********	***********	***********	***********	***********	***********	***********
0.2500	0.5000	0.7500	1:300	0.25	0.0417	0.0833	0.1251
0.3000	0.6000	0.9000	1:360	0.30	0.0500	0.1000	0.1500
0.4000	0.8000	1.1200	1:480	0.40	0.0667	0.1333	0.2001
0.5000	1.0000	1.5000	1:600	0.50	0.0833	0.1667	0.2499
1.0000	2.0000	3.0000	1:1,200	1.00	0.1667	0.3333	0.5001
2.0000	4.0000	6.0000	1:2,400	2.00	0.3333	0.6667	0.9999
4.0000	8.0000	12.0000	1:4,800	4.0	0.6667	1.3333	2.0001
5.0000	10.0000	15.0000	1:6,000	5.00	0.8333	1.6667	2.4999
8.0000	16.0000	24.0000	1:9,600	8.00	1.3333	2.6667	3.9999
10.0000	20.0000	30.0000	1:12,000	10.00	1.6667	3.3333	5.0001
20.0000	40.0000	60.0000	1:24,000	20.00	3.3333	6.6667	9.9999
30.0000	60.0000	90.0000	1:36,000	30.00	5.0000	10.0000	15.0000
40.0000	80.0000	120.0000	1:48,000	40.00	6.6667	13.3333	20.0001
52.8000	105.6000	158.4000	1:63,600	50.00	8.8000	17.6000	26.4000

* indicates the practical limit for aerial methods - for scales above this line, ground methods are normally used.
1 see Appendix A, Section A2.

MAP ACCURACY TEST (see Appendix A, Section A4)

Testing for horizontal accuracy compliance is done by comparing the planimetric (X and Y) coordinates of well-defined ground points to the coordinates of the same points as determined by a horizontal check survey of higher accuracy. The check survey shall be designed according to the Federal Geodetic Control Committee (FGCC) [FGCC, 1984] standards and specifications to achieve standard deviations equal to or less than *one third* of the "limiting rms error" selected for the map. The distance between control points (d) used in the FGCC standard for the design of the survey shall be the horizontal ground distance across the diagonal dimension of the map sheet.

Testing for vertical accuracy compliance shall be accomplished by comparing the elevations of well-defined points as determined from the map to corresponding elevations determined by a survey of higher accuracy. For purposes of checking elevations, the map position of the ground point may be shifted in any direction. The vertical check survey should be designed to produce rms errors in elevation differences at check point locations no larger than *1/20th of the contour interval.* The distance (d) between bench marks used in the FGCC standard for the design of the vertical check survey shall be the horizontal ground distance across the diagonal of the map sheet. Generally, vertical control networks based on surveys conducted according to the FGCC standards for Third Order provide adequate accuracy for conducting the vertical check survey.

Table 2
Planimetric and Vertical Coordinate Accuracy Requirements in Meters
Ground X or Y or Z for Well-defined Points[1]

Planimetric Classes (Limiting rms error, feet)					Vertical Classes (Limiting rms error, feet)		
CLASS 1	CLASS 2	CLASS 3	Map Scale	Contour Interval in feet	CLASS 1	CLASS 2	CLASS 3
0.0125	0.0250	0.0375	1:50	0.0125	0.0021	0.0042	0.0063
0.0250	0.0500	0.0750	1:100	0.0250	0.0042	0.0083	0.0125
0.0500	0.1000	0.1500	1:200	0.0500	0.0083	0.0167	0.0250
***********	***********	***********	***********	***********	***********	***********	***********
0.1000	0.2000	0.3000	1:400	0.1000	0.0167	0.0333	0.0500
0.1250	0.2500	0.3750	1:500	0.1250	0.0208	0.0417	0.0625
0.2000	0.4000	0.6000	1:800	0.2000	0.0333	0.0667	0.1000
0.2500	0.5000	0.7500	1:1,000	0.2500	0.0417	0.0833	0.1250
0.5000	1.0000	1.5000	1:2,000	0.5000	0.0833	0.1667	0.2500
1.0000	2.0000	3.0000	1:4,000	1.0000	0.1667	0.3333	0.5000
1.2500	2.5000	3.7500	1:5,000	1.2500	0.2083	0.4167	0.6250
1.8750	7.7500	5.6250	1:7,500	1.8750	0.3125	0.6250	0.9375
2.0000	4.0000	6.0000	1:8,000	2.0000	0.3333	0.6667	1.0000
2.5000	5.0000	7.5000	1:10,000	2.5000	0.4167	0.8333	1.2500
5.0000	10.0000	15.0000	1:20,000	5.0000	0.8333	1.6667	2.5000
10.0000	20.0000	30.0000	1:40,000	10.0000	1.6667	3.3333	5.0000
12.5000	25.0000	37.5000	1:50,000	12.5000	2.0833	4.1667	6.2500
25.0000	50.0000	75.0000	1:100,000	25.0000	4.1667	8.3333	12.5000

* indicates the practical limit for aerial methods - for scales above this line, ground methods are normally used.
1 see Appendix A, Section A2.

The same survey datums, both horizontal and vertical, must be used for both the project and the check control surveys. Although a national survey datum is highly recommended, a local datum is acceptable.

A minimum of 20 check points shall be established throughout the area covered by the map and shall be distributed in a manner agreed upon by the contracting parties (see Appendix A, Section A5).

Maps produced according to this spatial accuracy standard shall include the following statement in the title block:

THIS MAP WAS COMPILED TO MEET THE COMMONWEALTH OF VIRGINIA STANDARD FOR CLASS 1 MAP ACCURACY AS OF <date of map compilation>

Tests for compliance of a mapsheet are optional. If the map was checked and found to conform to this spatial accuracy standard, the following statement shall appear in the title block:

THIS MAP WAS CHECKED AND FOUND TO CONFORM TO THE COMMONWEALTH OF VIRGINIA STANDARD FOR CLASS 1 MAP ACCURACY AS OF <date of map compilation>

APPENDIX A

EXPLANATORY COMMENTS

A1. Root Mean Square Error

The "root mean square" rms error is defined to be the square root of the average of the squared discrepancies. In this case, the discrepancies are the differences in coordinate or elevation values as derived from the map and as determined by an independent survey of higher accuracy (check survey). For example, the rms error in the X coordinate direction can be computed as:

$$rms = \sqrt{(D2/n)}$$

where:

$D2 = d12 + d22 + \text{---------} + dn2$

d = discrepancy in the X coordinate direction = $X_{map} - X_{check}$

n = total number of points checked on the map in the X coordinate direction

A2. Well-defined Points

The term "well-defined points" pertains to features that can be sharply identified as discrete points. Points which are not well-defined (that is poorly-defined) are excluded from the map accuracy test. In the case of poorly-defined image points, these may be of features that do not have a well-defined center such as roads that intersect at shallow angles [U.S. National Map Accuracy Standards, 1941]. In the case of poorly defined ground points, these may be such features as soil boundaries or timber boundaries. The selection of well-defined points is made through agreement by the contracting parties.

A3. Relationship to U. S. National Map Accuracy Standards

Planimetric accuracy in terms of the "limiting rms error" can be related to the United States National Map Accuracy Standards (NMAS) provided the following assumptions are made:

- the discrepancies are normally distributed about a zero mean
- the standard deviations in the X and Y coordinate directions are equal
- sufficient check points are used to accurately estimate the variances

To compute the "circular map accuracy standard" (CMAS) which corresponds to the 90% circular map error defined in the NMAS [ACIC, 1962, p.26, p. 41]:

$$CMAS = 2.146\ \sigma x \qquad \text{or:} \qquad CMAS = 2.146\ \sigma y$$

Given these relationships and assumptions, the limiting rms errors correspond approximately to the CMAS of 1/47th of an inch for all errors and related scales indicated in Table 1. For the metric cases indicated in Table 2, the CMAS is 0.54 mm for all rms errors and corresponding scales. It is emphasized that for the Commonwealth of Virginia Standard, spatial accuracies are stated and evaluated at *full or ground scale*. The measures in terms of equivalent CMAS are only approximate and are offered only to provide a comparison to the National Map Accuracy Standard of CMAS of 1/30th inch at map scale.

A4. Check Survey

Both the vertical and horizontal (planimetric) check surveys are designed based on the National standards of accuracy and field specifications for control surveys established by the Federal Geodetic Control Committee (FGCC). These standards and specifications [FGCC, 1984] are intended to establish procedures which produce accuracies in terms of relative errors. For horizontal surveys, the proportional accuracies for the various orders and classes of survey are stated in Table 2.1 of the FGCC document and for elevation accuracy in Table 2.2. These tables along with their explanations are reproduced below. From FGCC [1984]:

2.1 HORIZONTAL CONTROL NETWORK STANDARDS

When a horizontal control is classified with a particular order and class, NGS certifies that the geodetic latitude and longitude of that control point bear a relation of specific accuracy to the coordinates of all other points in the horizontal control network. This relationship is expressed as a distance accuracy, 1:a. A distance accuracy is the ratio of relative positional error of a pair of control points to the horizontal separation of those points.

Table 2.1
Distance Accuracy Standards

Classification	Minimum distance accuracy
First-order	1: 100,000
Second-order, class I	1: 50,000
Second-order, class II	1: 20,000
Third-order, class I	1: 10,000
Third-order, class II	1: 5,000

A distance accuracy, 1:a, is computed from a minimally constrained, correctly weighted, least square adjustment by:

$$a = d/s$$

where

a = distance accuracy denominator

s = propagated standard deviation of distance between survey points obtained from the least squares adjustment
d = distance between survey points

correctly weighted means that prior knowledge of the accuracy of points is applied in their weighting

2.2 VERTICAL CONTROL NETWORK STANDARDS

When a vertical control point is classified with a particular order and class, NGS certifies that the orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relationship is expressed as an elevation accuracy, b. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes.

Table 2.2
Elevation Accuracy Standards

Classification	Maximum elevation difference accuracy
First-order	0.5
Second-order, class I	0.7
Second-order, class II	1.0
Third-order, class I	1.3
Third-order, class II	2.0

An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least square adjustment by:

$$b = S/\sqrt{d}$$

where

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes

S = propagated standard deviation of elevation difference in millimeters between survey points obtained from a least squares adjustment. Note that the units of b are $(mm)/\sqrt{(km)}$.

correctly weighted means that prior knowledge of the accuracy of points is applied in their weighting

For an example of designing a check survey (selecting an order and class), assume that a survey is to be designed to check a map which is intended to possess a planimetric (horizontal) "limiting rms error" (see Table 1 of the map standard) of *one* foot and a contour interval of *two* feet. In contrast to survey accuracies, which are stated in terms of relative horizontal distances to adjacent points, map features are intended to possess accuracies relative to all other points appearing on the map. Therefore, for purposes of the check survey, the distance between survey points (d) is taken as the diagonal distance on the ground across the area covered by the map. According to the FGCC survey standards this is the distance across which the "minimum distance accuracy" and "maximum elevation difference accuracy" are required (see Table 2.1 and 2.2 of the [FGCC, 1984] document).

For the planimetric check survey, assume that the diagonal distance on the ground covered by the map is 6,000 feet. The propagated standard deviation (s) required for the check survey is one-third of the limiting rms error of one foot or 0.33 foot in this example. Returning to the equation from the FGCC [1984] document relating distance between survey points (d), standard deviation (s) and distance accuracy denominator (a):

$$a = d/s = (6000 \text{ feet})/(0.33 \text{ feet}) = 18{,}182$$

By referring to Table 2.1 of the FGCC document, it is clear that a control survey designed according to the standards and specifications for second-order, class II is required to produce the horizontal check survey for this example. If the project control survey is conducted at a standard of accuracy equal to or better than second-order, class II, the check survey can tie to the project control network in accordance with FGCC standards.

For the vertical check survey, the distance (d) is also taken as a diagonal ground distance across the map to account for the fact that elevation accuracy pertains to all mapped features. The propagated standard deviation in elevation (S) is required by this standard to be equal or less than 1/20th of the contour interval (CI) of two feet:

$$S = (1/20)\ CI = 0.10 \text{ feet}$$

Returning to Table 2.2 of the FGCC document, relating distance between bench marks (d in km), the standard deviation in elevation (S in mm), and the elevation difference accuracy (b);

where;

$S = 0.10$ feet $= 30.5$ mm

$d = 6000$ feet $= 1.181$ km

then;

$$b = S/\sqrt{d} = 28.1 \text{ mm}/\sqrt{\text{km}}$$

It is clear that a third-order survey for elevation differences is more than adequate for purposes of conducting the check survey for this map example. Other methods for conducting the check survey for elevation are acceptable provided they have demonstrated accuracy capability equal to that required by this map standard. Such departures, however, must be agreed upon by the contracting parties prior to conducting the survey.

A5. Check Point Location

Due to the diversity of requirements anticipated for any special purpose or engineering map, it is not realistic to include statements that specify the spatial distribution of check points designed to assess the spatial accuracy of the map. For instance, it may be preferred to distribute the check points more densely in the vicinity of important structures or drainage features and more sparsely in areas that are of little or no interest.

For a map sheet, however, of conventional rectangular dimensions, intended to portray a uniform spatial accuracy over the entire map sheet, it may be reasonable to specify the distribution. For instance, given the minimum of twenty check points, it could be specified that at least 20% of the points be located in each quadrant of the map sheet and that these points be spaced at intervals equal to at least 10% of the map sheet diagonal.

APPENDIX B

UNITED STATES NATIONAL MAP ACCURACY STANDARDS

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standards or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. ***Horizontal accuracy***. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general, what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two roads or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. ***Vertical accuracy***, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. ***The accuracy of any map may be tested*** by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. ***Published maps meeting these accuracy requirements*** shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

5. ***Published maps whose errors exceed those aforestated*** shall omit from their legends all mention of standard accuracy.

6. ***When a published map is a considerable enlargement*** of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This map is an enlargement of a 1:24,000-scale published map."

7. ***To facilitate ready interchange and use of basic information for map construction*** among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

U.S. BUREAU OF THE BUDGET

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