Map Accuracy Standards

Mentoring Mondays
4 May 2026
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I. Introduction
II. Primary Standards
III. Other Standards?
IV. Scale

A. Spatial Data Accuracy

I. Introduction

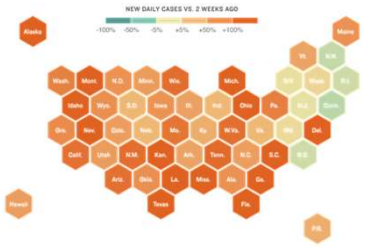
1. What's a Map?

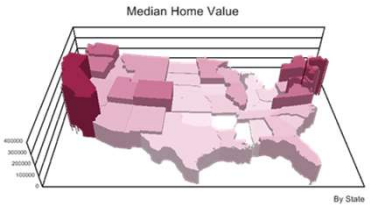
A map is a graphic abstraction of some aspect of reality.

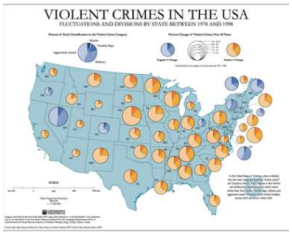
a. Thematic: conveys information visually

Spatial locations are for reference

Not intended for measurement







Map Accuracy Standards

Mentoring Monday

A. Spatial Data Accuracy

I. Introduction

1. What's a Map?

A map is a graphic abstraction of some aspect of reality.

b. Metric: information depicted in spatially correct locations and relationships

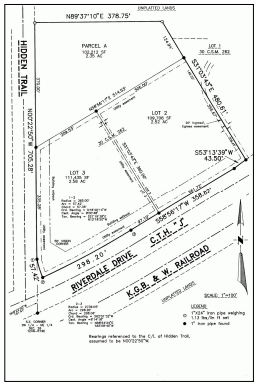
Can make measure on them or otherwise extract spatial information.

Common metric maps

Planimetric – 2D horizontal features

Topographic – basic planimetric with elevations added

Cadastral – planimetric or topographic on boundary lines base



Map Accuracy Standards

Mentoring Monday

A. Spatial Data Accuracy

I. Introduction

2. Metric map accuracy

If it's not indicated on the map, can accuracy be inferred from map's

purpose

source

scale?

With a few exceptions, these aren't definitive nor qualitative.

Without some accuracy indicator, the user doesn't know:

if the information is **correctly** presented

where everything is supposed to be

if the information is **truly** presented

does the map imply an accuracy it doesn't have?

Map Accuracy Standards

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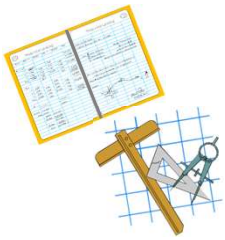
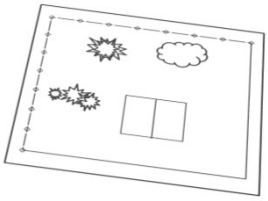
B. Graphic Abstraction

I. Introduction

1. In the old days....
   - All maps were scaled drawings on physical media
     - Reality was abstracted to a graphic representation.
   - Physical measurements were scaled to fit a paper or mylar sheet
   - Data quantity and accuracy driven by scale and purpose.

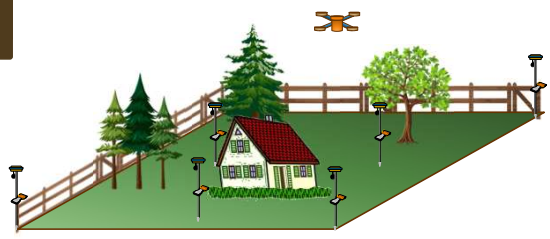


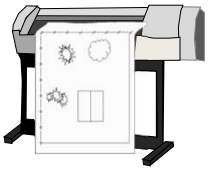


B. Graphic Abstraction

I. Introduction

2. Current practice...
   - Spatial data is collected and managed digitally.
     - CAD is done real size.
   - Scale is irrelevant, unless it is plotted on physical medium.
     - Plats, Plan sets, etc
   - Data quantity and accuracy driven by purpose.





C. Need for Standards

I. Introduction

When accuracy is important, standards are needed.

Standards may be:

- a priori: accuracy level to achieve
- a posteriori: accuracy level that is achieved

The most common national formal standards are:

- US National Map Accuracy Standards (USNMAS)
- American Society of Photogrammetry and Remote Sensing (ASPRS)
- National Standard for Spatial Data Accuracy (NSSDA)

These are a posteriori standards.

- When used they affect the data collection: method, density, etc
- Identification should be carried with the product, graphic or digital: metadata

Map Accuracy Standards

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A. USNMAS

II. Primary Standards

US National Map Accuracy Standards

Date back to 1937; latest version is 1947

Developed by Federal agencies that created/used publicly funded maps

Purposes:

- To assure the graphic accuracy of publicly funded maps.
- Ensure efficient accurate data exchange between federal agencies.

Map Accuracy Standards

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A. USNMAS

II. Primary Standards

Vertical

Not more than **10 percent** of the elevations tested shall be in error by 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.

Horizontal

Not more than **10 percent** of points tested on a map shall be in error by more than:

1/30 inch at scales larger than 1:20,000,

1/50 inch at scales of 1:20,000 or smaller.

Points are measured at map scale.

Accuracy limits only apply to positions of well-defined points.

Note that both represent a 90% CI.

Map Accuracy Standards

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A. USNMAS

II. Primary Standards

Example: USGS 7.5' topoquad

Horizontal standard

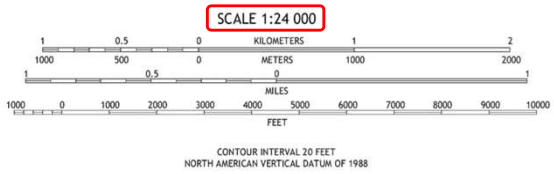
Scale 1:24,000 < 1:20,000

Use 1/50 in positional accuracy.

1/50 in x 24,000/1 = 480 in

480 in x (1 ft/12 in) = 40 ft

90% of tested points must be within **±40 ft** of their horizontal map position.



Map Accuracy Standards

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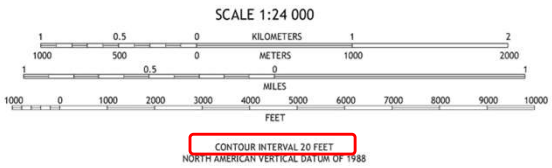
A. USNMAS

II. Primary Standards

Example: USGS 7.5' topoquad



Vertical standard

Contour Interval = 20 ft

1/2 x 20 ft = 10 ft

90% of tested points must be within **±10 ft** of their vertical map position.

A. USNMAS

II. Primary Standards

Evaluation Method

Mapped positions must be compared to ground positions to determine in the USNMAS have been met. In the old days, this was called *ground truthing*.

1. Test points
   - Must be selected throughout the area. Number and dispersion affected by:
     - Size of area; Terrain; Landcover
   - Horizontal points must be distinct both on map and ground.
   - In low feature areas, elevations are checked at map coordinates.
2. Ground survey
   - Must be done using technology that is more accurate than the map.
   - With typical small scales, GPS may be overkill. Can use Total station traverses & radial survey, Photogrammetry, airborne scanning; profile levels, other data sources
3. Comparison
   - Straightforward comps like the example. 90% passing is acceptable to meet USNMAS

Map Accuracy Standards

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A. USNMAS

II. Primary Standards

Shortcomings

USNMAS specifically addresses maps at scales much smaller than typically used locally.

In particular, its horizontal component allowed for greater error at smaller scales.

It was also based on paper products; did not evolve to adapt to digital data.

Accuracy in terms of paper scale

Example

1 in = 100 ft; 2 ft CI

Horizontal

(1 in=100 ft) > (1:20,000); use 1/30 inch

1/30 in (100 ft/1 in) = **3.3 ft**

We generally need higher accuracy at that scale

Vertical

2 ft x (1/2) = **1 ft**

Map Accuracy Standards

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B. ASPRS

II. Primary Standards

American Society of Photogrammetry and Remote Sensing

1. *Accuracy Standards for Large Scale Maps* (1990)

First standard to deal with large scale paper maps.

Used Root Mean Square Errors (RMSE) to define three levels of map accuracy.

2. Revised in 2014: *Positional Accuracy Standards for Digital Geospatial Data,* Ed 1 Ver 1 (26 pages)

Emphasis shifted to digital data position accuracy; Based on FGDC NSSDA

Add 95% CI accuracy level of horizontal and vertical position data to existing RMSE.

Classification is terms of RSME achieved (eg, 10 cm, 20 cm, etc)

3. Refined in 2024: *Positional Accuracy Standards for Digital Geospatial Data,* Ed 2 Ver 2 (228 pages)

Expanded digital data acquisition sources (eg. Lidar).

Increase description of field data verification methods incorporating different technologies.

Map Accuracy Standards

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B. ASPRS

II. Primary Standards

Positional Accuracy Standards for Digital Geospatial Data

Modern approach (similar to survey standards evolution)

- Instead of tying spatial data accuracy to a map scale, it's instead based on project or mapping needs.
- First two versions of the standards bridged the gap between USNMAS to NSSDA.

- Latest PASDCD heavily based on the NSSDA but adds more support information aspects
  - field surveys
  - data point selection
  - formal accuracy reporting
  - examples
  - more detail discussion of accuracy statistics

C. NSSDA

II. Primary Standards

National Standard for Spatial Data Accuracy (NSSDA), 1998

- Applicable to digital or paper-based data.
- Uses RMSE to specify positional accuracy at 95% CI.
  - Forms nucleus of ASPRS standards
- NSSDA does not define pass/fail criteria like USNMAS.
  - Up to users to define allowable RMSE & then use as contracting specs if existing data not sufficiently accurate

RSME calculations

$$RMSE_x = \sqrt{\frac{\sum (x_{d,i} - x_{s,i})^2}{n}}$$

$$RMSE_y = \sqrt{\frac{\sum (y_{d,i} - y_{s,i})^2}{n}}$$

$$RMSE_z = \sqrt{\frac{\sum (z_{d,i} - z_{s,i})^2}{n}}$$

x_d, y_d, z_d dataset coord & elev

x_s, y_s, z_s surveyed coord & elev

C. NSSDA

II. Primary Standards

National Standard for Spatial Data Accuracy (NSSDA), 1998

NSSDA accuracy recommendations

Horizontal: Circular error

If $RMSE_x = RMSE_y$

$$RMSE_r = \sqrt{2 \times RMSE_x^2} = \sqrt{2 \times RMSE_y^2}$$

$$Accy_r = 1.7308 \times RMSE_r$$

If $RMSE_x \neq RMSE_y$ approximate circular error

$$RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}$$

$$Accy_r = 2.4477 \times 0.5 \times (RMSE_x + RMSE_y)$$

Vertical

$$Accy_z = 1.9600 \times RMSE_z$$

NSSDA only specifies analysis methodology and 95% CI multiplier.

User is responsible for determining RSME level(s).

C. NSSDA

II. Primary Standards

National Standard for Spatial Data Accuracy (NSSDA), 1998

Evaluation Guidelines

Post-collection, the digital data is compared to their ground equivalents to determine differences. Similar to USNMAS method except more rigid statistics.

1. Well-defined points
   - Must be discernible in the digital product as well as on the ground.
   - Targets, fence lines, manholes, intersections, etc.
2. Independent data acquisition using higher accuracy technology
   - The ground positions must be determined to a high accuracy than the digital positions.
   - Depends on how the digital data was acquired
   - GPS (RTK, VPN, etc) common method, Total station survey
   - In some cases, photogrammetry can be used as well as drone scanning.

C. NSSDA

II. Primary Standards

National Standard for Spatial Data Accuracy (NSSDA), 1998

Evaluation Guidelines

3. Check Point Location

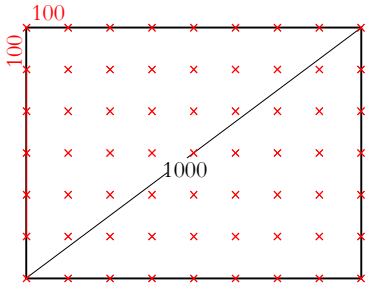
At least 20, but number of points and dispersion dependent on many factors. Similar to USNMAS:

Size of area; Terrain; Landcover

If a rectangular area with assumed uniform accuracy, suggest:

spaced at 10% of diagonal distance across dataset

and at least 20% in each quadrant.



C. NSSDA

II. Primary Standards

Example

	Digital Data			Surveyed Data		
Pt	x_d	y_d	z_d	X_s	Y_s	Z_s
GCP1	3,584.394	7,449.934	477.127	3,584.534	7,450.004	477.198
GCP2	3,872.190	12,939.180	412.406	3,872.290	12,939.280	412.396
GCP3	3,893.089	1,979.824	487.292	3,893.072	1,979.894	487.190
GCP4	3,927.194	16,084.129	393.591	3,927.264	16,083.979	393.691
GCP5	16,737.074	16,675.999	451.305	16,736.944	16,675.879	451.218

State Plane Coordinates with constants subtracted

x: 356,000

y: 5,135,000

Units are feet

C. NSSDA

II. Primary Standards

Example

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Pt	x_d	y_d	z_d	X_s	Y_s	Z_s
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GCP5	16,737.074	16,675.999	451.305	16,736.944	16,675.879	451.218

Pt	diff = (Digital) - (Surveyed)					
GCP1	dx	dy	dz	dx^2	dy^2	dz^2
GCP2	-0.140	-0.070	-0.071	0.019600	0.004900	0.005041
GCP3	-0.100	-0.100	0.010	0.010000	0.010000	0.000100
GCP4	0.017	-0.070	0.102	0.000289	0.004900	0.010404
GCP5	-0.070	0.150	-0.100	0.004900	0.022500	0.010000	
	0.130	0.120	0.087	0.016900	0.014400	0.007569
			Σd^2	0.051689	0.056700	0.033114
			RMSE	0.1017	0.1065	0.0814

$$RMSE_x = \sqrt{\frac{\sum (x_{d,i} - x_{s,i})^2}{n}}$$

$$RMSE_y = \sqrt{\frac{\sum (y_{d,i} - y_{s,i})^2}{n}}$$

$$RMSE_z = \sqrt{\frac{\sum (z_{d,i} - z_{s,i})^2}{n}}$$

$RMSE_x = RSME_y$?

Map Accuracy Standards

Mentoring Monday

C. NSSDA

II. Primary Standards

Example

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	0.130	0.120	0.087	0.016900	0.014400	0.007569
			Σd^2	0.051689	0.056700	0.033114
			RMSE	0.1017	0.1065	0.0814

$RMSE_x \neq RSME_y$

$$RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}$$
$$= \sqrt{0.1017^2 + 0.1065^2}$$
$$= 0.147$$

$$Accy_r = 2.4477 \times 0.5 \times (RMSE_x + RMSE_y)$$
$$= 2.4477 \times 0.5 \times (0.1017 + 0.1065)$$
$$= 0.255$$

Map Accuracy Standards

Mentoring Monday

A. 3DEP Topo Data Quality Levels (QLs)

III. Other Standards?

3DEP: 3D Elevation Program

Creation of nationwide high quality topographic and 3D data.

Many states have statewide Lidar coverage collected under the 3DEP program.

3DEP accuracy standards are:

Table 1: Lidar quality level requirements defined in the 3DEP Lidar Base Specification

QUALITY LEVEL	DATA SOURCE	VERTICAL ACCURACY RMSEz (cm)	NOMINAL PULSE SPACING (NPS) meters	NOMINAL PULSE DENSITY (NPD) points per square meter	DIGITAL ELEVATION MODEL (DEM) cell size (meters)
QL0	**Lidar**	**5 cm**	**<= 0.35 m**	**>= 8 pts/square meter**	**0.5 m**
QL1	**Lidar**	**10 cm**	**<= 0.35 m**	**>= 8 pts/square meter**	**0.5 m**
QL2	**Lidar**	**10 cm**	**<= 0.71 m**	**>= 2 pts/square meter**	**1 m**
QL3	Lidar	20 cm	<= 1.41 m	>= 0.5 pts/square meter	2m
QL4	Imagery	139 cm	N/A	N/A	5 m
QL5	IfSAR	185 cm	N/A	N/A	5 m

States, Counties, Cities that contract additional scanning us the 3DEP Qls as quality specs.

Map Accuracy Standards

Mentoring Monday

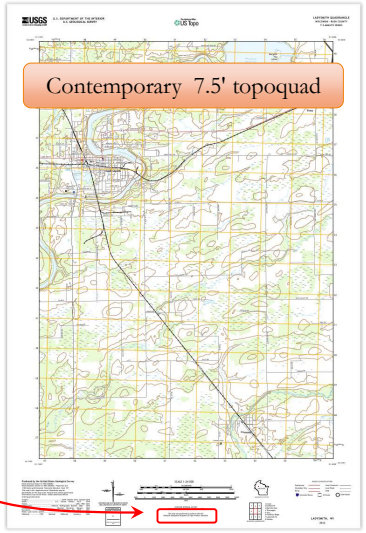
B. US Topo Product Standard

III. Other Standards?

Due to the diversity of data collection methods and the ability to integrate them in digital spatial databases (eg, GIS) assigning an accuracy on the final product can be difficult.

What does this mean?

This map was produced to conform with the National Geospatial Program US Topo Product Standard.



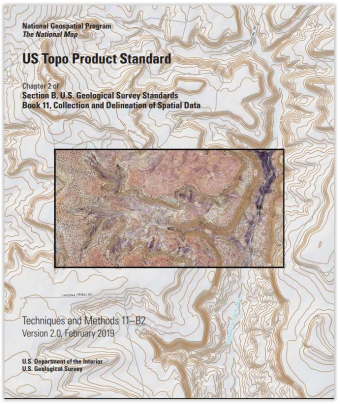
Map Accuracy Standards

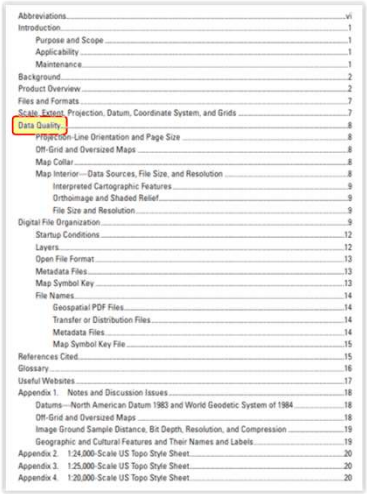
Mentoring Monday

B. US Topo Product Standard

III. Other Standards?

The standard is primarily for map content and composition.





Map Accuracy Standards

Mentoring Monday

B. US Topo Product Standard

III. Other Standards?

Data Quality

Components of data quality include currency, consistency, completeness, and accuracy. The US Topo program uses interpreted cartographic point, line, and area features taken from databases maintained or approved by the USGS. These source databases are multipurpose GIS databases and are not necessarily complete or consistent in the same sense that is represented on historical topographic map series. The databases are often compiled from multiple primary and secondary sources and have no single currency date. US Topo maps therefore have different characteristics regarding currency, consistency, and completeness compared to historical USGS topographic maps. The data tend to be more current than on a legacy map but may be less consistent between maps and between regions because of variations in data collection between different sources.

Accuracy, both positional accuracy and attribute accuracy, of the data is the responsibility of the organization that produced the source data. The overall quality of the cartographic data depends directly on the quality of the source GIS databases. US Topo maps produced to date do not include a traditional accuracy statement in the map collar because of the variety of data sources used in creating them. The USGS cartographically adjusts and generalizes the data used in US Topo maps where necessary. The XML metadata file attached to each map includes data-quality statements in the Data Quality, Accuracy Information, Data Source, and Process Information sections for each individual data layer.

Map Accuracy Standards

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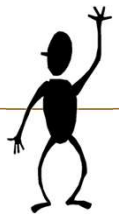
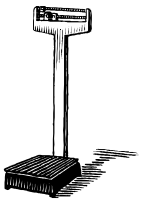
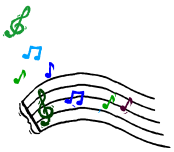
Questions?



A. Definition
B. Scale Expression
C. Small vs Large Scale



IV. Scale

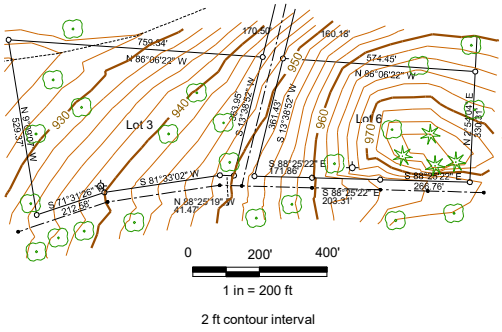


A. Definition

II. Scale

Scale means two things:

1. The dimensional proportion of an object's map representation and the object's size.
   - Horizontal and Vertical
     - Example



Map Accuracy Standards

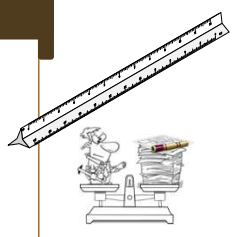
Mentoring Monday

A. Definition

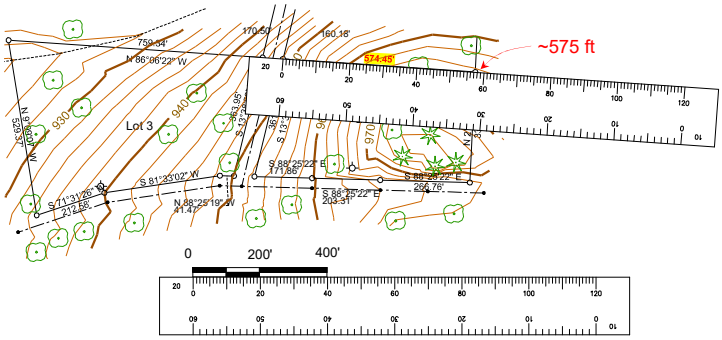
II. Scale

Scale means two things:

1. The dimensional proportion of an object's map representation and the object's size.
2. A device with a system of ordered marks that is used to measure objects that are drawn to some proportion.
   - Matching scales allows direct ground distance determination form a map.



Engineer's Scales



Map Accuracy Standards

Mentoring Monday

B. Scale Expression

II. Scale

1. Statement
   a. Equivalence – mixed units
      engr: 1 drawing unit = XX real units
      1 in = 200 ft
      architectural: xx inches = 1 ft real unit
      3/8" = 1'

   b. Ratio – same units
      1 drawing unit = XX real units
      1:24,000

"1 to 100" **is not** the same as "1 in = 100 ft"

1 in = 200 ft is the same as 1: _____

1:600 is the same as 1 in = _____ ft

Map Accuracy Standards

Mentoring Monday

B. Scale Expression

II. Scale

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      engr: 1 drawing unit = XX real units
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      1:24,000

"1 to 100" **is not** the same as "1 in = 100 ft"

1 in = 200 ft is the same as 1: 2400

1:600 is the same as 1 in = 50 ft

Map Accuracy Standards

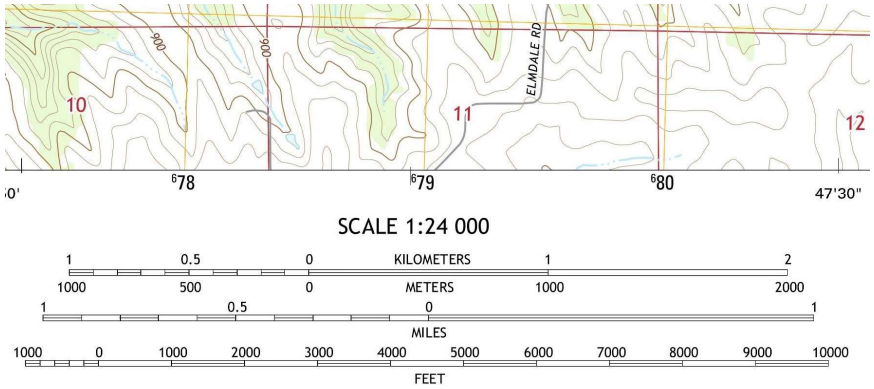
Mentoring Monday

B. Scale Expression

II. Scale

2. Graphic

A built-in measuring "instrument" on the drawing.



Map Accuracy Standards

Mentoring Monday

B. Scale Expression

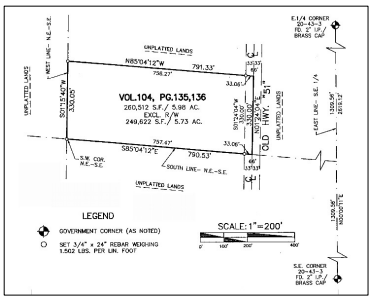
II. Scale

2. Graphic

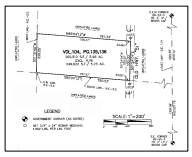
A drawing generally includes both a scale statement and a graphic scale. Why?

A scale statement is correctly sized only when the map is plotted at that scale.

A graphic scale is correct at any plotted map size.



Original: 24"x18"; 1 in = 200 ft



Plot: 12"x9"; 1 in = ?

Map Accuracy Standards

Mentoring Monday

D. Small v Large Scale

II. Scale

1. Relative

"Small" and "Large" are relative terms with regard to drawn size of an object.

Example: 800 ft by 400 ft parcel

at 1 in = 100 ft

$$l = 800\ ft \times \left(1\ in/100\ ft\right) = 8.0\ in$$
$$w = 400\ ft \times \left(1\ in/100\ ft\right) = 4.0\ in$$

at 1 in = 200 ft

$$l = 800\ ft \times \left(1\ in/200\ ft\right) = 4.0\ in$$
$$w = 400\ ft \times \left(1\ in/200\ ft\right) = 2.0\ in$$

8.0"

1"=100' 4.0"

4.0"

1"=200' 2.0"

Parcl is *larger* at 1 in = 100 ft than at 1 in = 200 ft

∴ 1 in = 100 ft is larger scale than 1 in = 200 ft

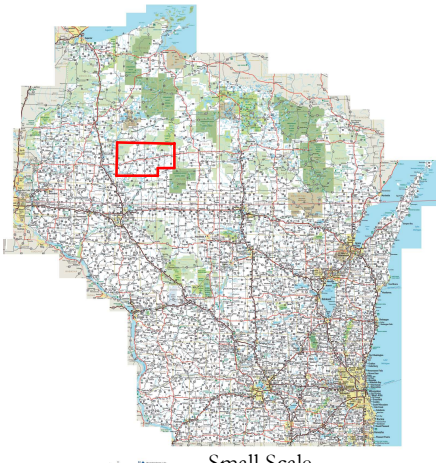
Map Accuracy Standards

Mentoring Monday

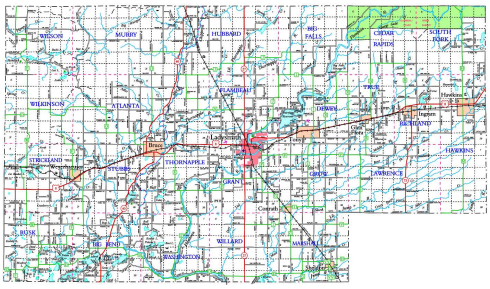
D. Small v Large Scale

II. Scale

2. Perspective



Small Scale



Large Scale

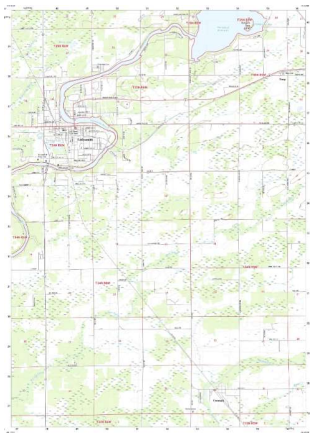
Map Accuracy Standards

Mentoring Monday

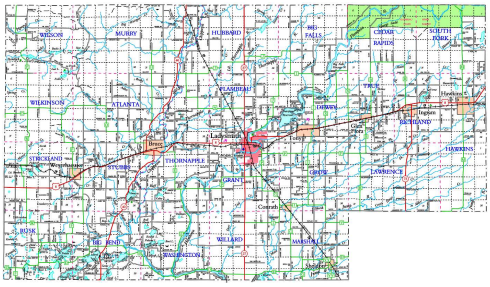
D. Small v Large Scale

II. Scale

2. Perspective



Large Scale



Small Scale

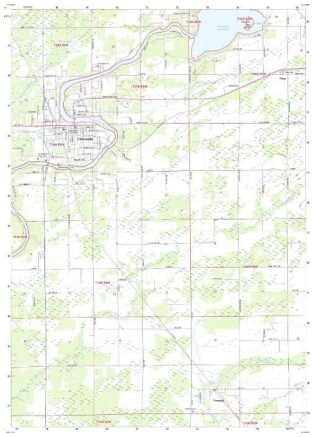
Map Accuracy Standards

Mentoring Monday

D. Small v Large Scale

II. Scale

2. Perspective



Small Scale

Large Scale

Map Accuracy Standards

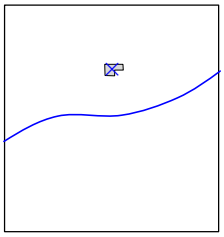
Mentoring Monday

D. Small v Large Scale

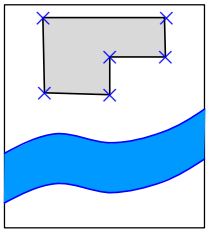
II. Scale

3. Generalization

Data density: Need less data to depict features at smaller scales.



Small scale
Building
Point symbol, single data point
River
Simple linear symbol



Large scale
Building
Corner locations; six data points
River
More complex symbol; polygon

Map Accuracy Standards

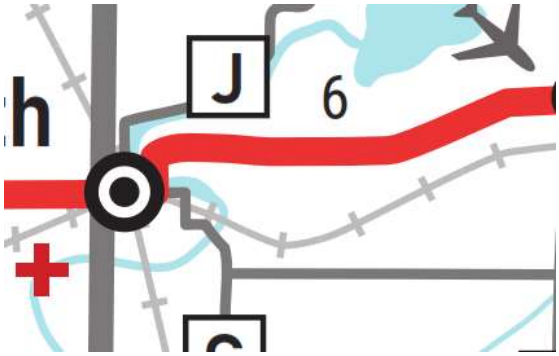
Mentoring Monday

D. Small v Large Scale

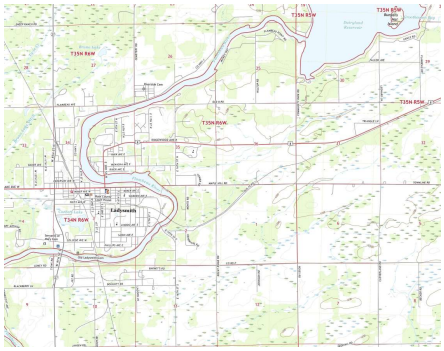
II. Scale

3. Generalization

Example: same area compiled at two different scales.



State Highway Map
1:800,000



7.5 minute quadrangle
1:24,000

Map Accuracy Standards

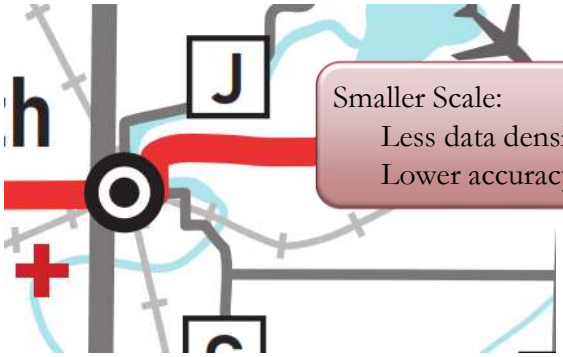
Mentoring Monday

D. Small v Large Scale

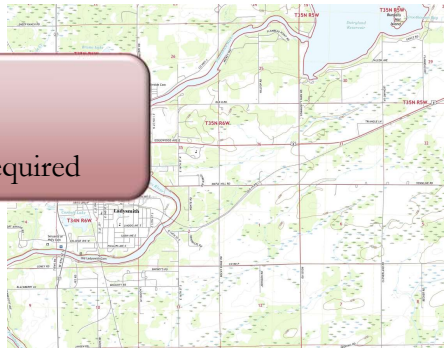
II. Scale

3. Generalization

Example: same area compiled at two different scales.



Smaller Scale:
- Less data density
- Lower accuracy required



State Highway Map
1:800,000

7.5 minute quadrangle
1:24,000

Map Accuracy Standards

Mentoring Monday

Out of Curiosity...

IV. Scale

When plotting digital data on physical media, you have to decide what scale to use.

Obviously, you want the plot to be as large on the media as possible, leaving space for margins, but then you wind up with a scale like 1 in = 835.6 ft or 1 in = 51.5 ft, etc.

What do you select for a scale and why?

Map Accuracy Standards

Mentoring Monday

Out of Curiosity...

IV. Scale

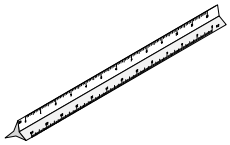
When plotting digital data on physical media, you have to decide what scale to use.

Obviously, you want the plot to be as large on the media as possible, leaving space for margins, but then you wind up with a scale like 1 in = 835.6 ft or 1 in = 51.5 ft, etc.

What do you select for a scale and why?

Engineer's Scale

- 3 sides with 6 scales
- 10-20-30-40-50-60 divisions per inch



Div	Scales used with this division		
10	1"=1'	1"=10'	1"=100'
20	1"=2'	1"=20'	1"=200'
30	1"=3'	1"=30'	1"=300'
40	1"=4'	1"=40'	1"=400'
50	1"=5'	1"=50'	1"=500'
60	1"=6'	1"=60'	1"=600'

Map Accuracy Standards

Mentoring Monday

Questions?