Oregon Department of Transportation

History & Development of the Oregon Coordinate Reference System

Oregon GPS Users Group
Roseburg, OR
15 March 2017

Ken Bays, PLS
Lead Geodetic Surveyor
Oregon Dept. of Transportation

Overview

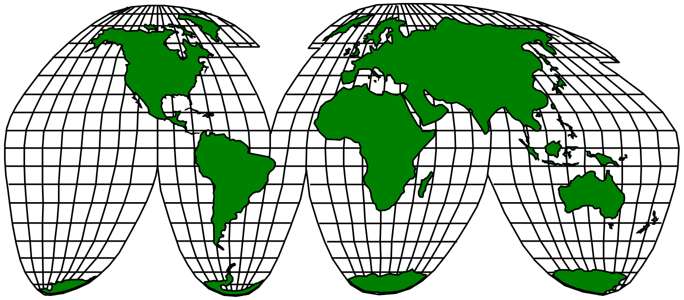
- Why the OCRS was developed. What was the need?
- Best practices used to design the OCRS
- Path & timeline to develop the OCRS
- Distortion maps: the original 20 and the 19 new OCRS zones

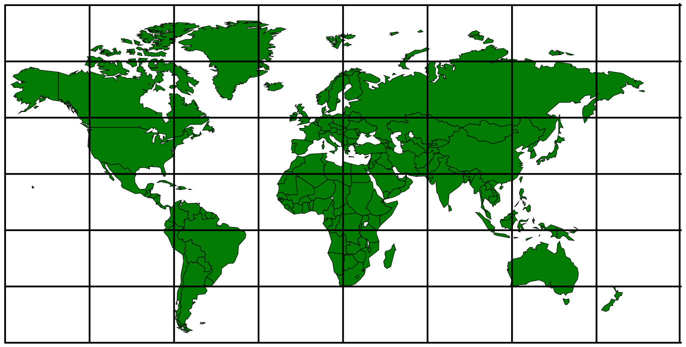
Why the OCRS was developed: What was the need?

- Problems with the legacy State Plane Coordinate system
- ODOT Engineering Automation goals
  - Key Concepts for a 25 Year Time Horizon

Mapping Projections

- A mapping projection relates the coordinates of points on a curved earth's surface with the coordinates of the same points on a plane, or flat surface.

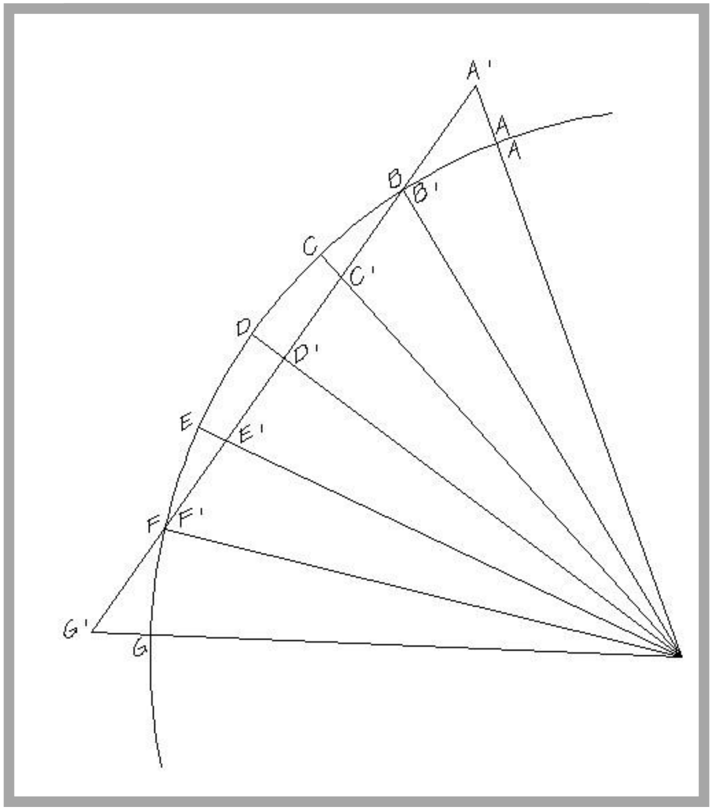




- Allows projection of a spherical surface onto a flat surface.

Map Projection

- It is impossible to represent a curved surface on a plane without introducing distortion of:
  - Angles
  - Azimuths
  - Distances
  - Areas
- An appropriate map projection must be chosen such that some of the four remain undistorted.



GEODETIC LETTER

STATE PLANE COORDINATES

No. 1
Vol. 4

JANUARY
1937

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UNITED · STATES · COAST · AND · GEODETIC · SURVEY ·
WASHINGTON D.C.

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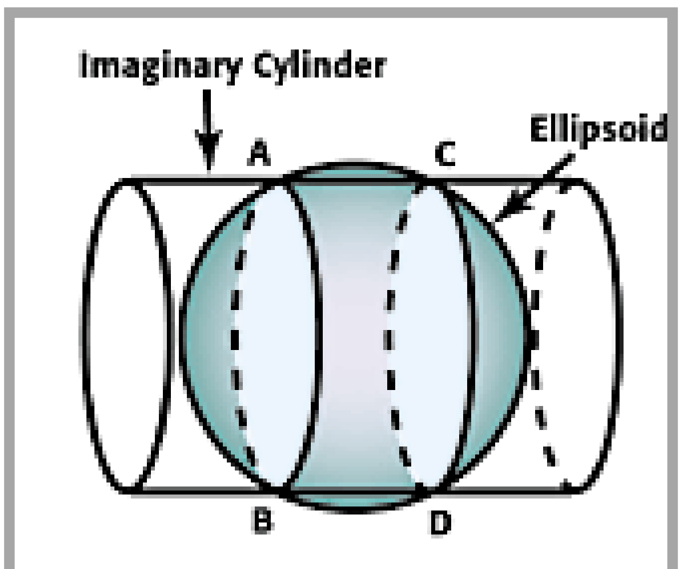
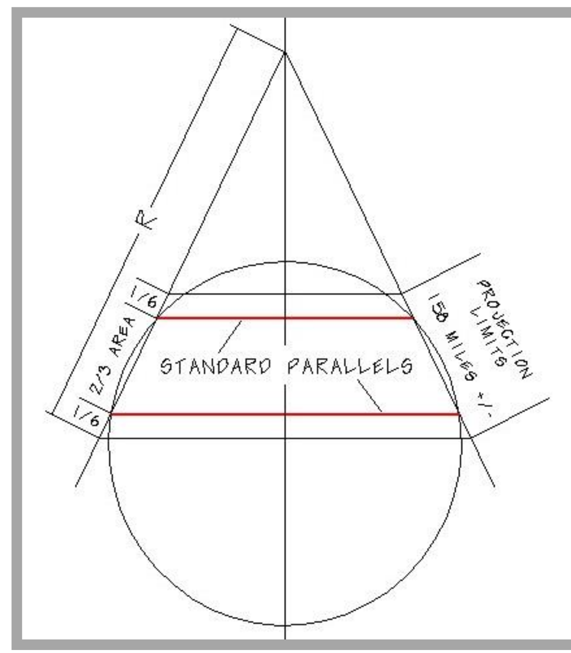
State Plane Coordinate Systems

- Developed by USC & GS in 1933 at the request of an engineer from the North Carolina Highway Department
- Two main projection types used:



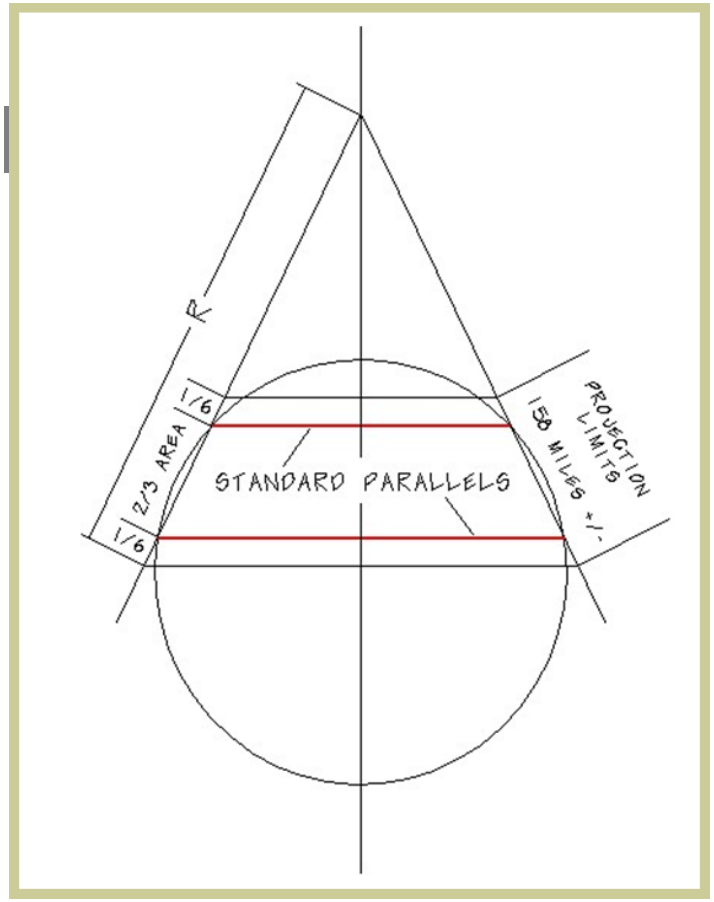
Transverse Mercator



Lambert Conformal Conic

Oregon State Plane System

- Developed by USC & GS in 1938
- Given legal status by Oregon in 1945
- Lambert Conformal Conic Projections
- 2 zones: North zone & South zone
- Each zone is 158 miles wide
- Maximum projection distortion 1:10,000
- Original Ellipsoid used was at approximate sea level height or ground for North America
- No consideration for distortion resulting from ground height above the ellipsoid



Problems with State Plane Coordinate Projections

- Do not represent ground distances
- Do not minimize distortion over large areas
- Do not reduce convergence angle
- Do not support modern surveying accuracy requirements

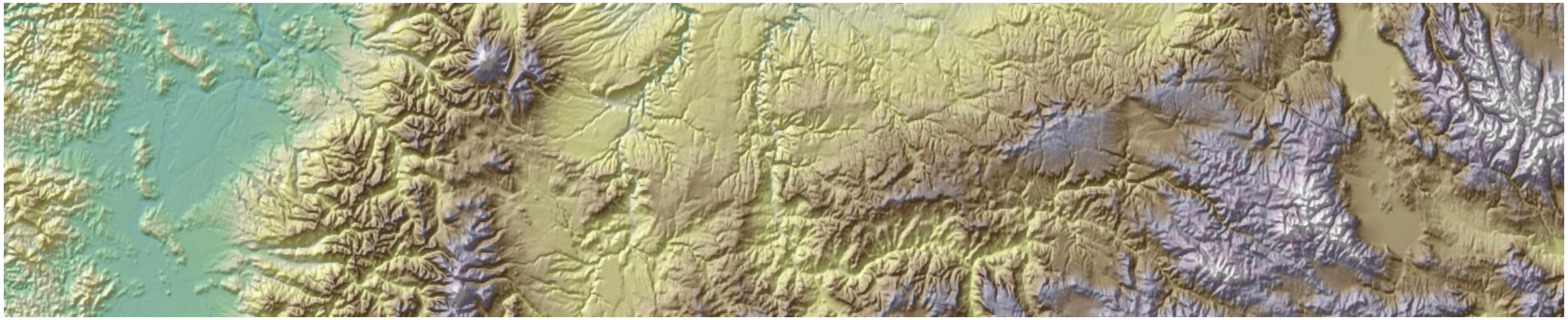
Oregon Department of Transportation

Distortion due to Earth Curvature

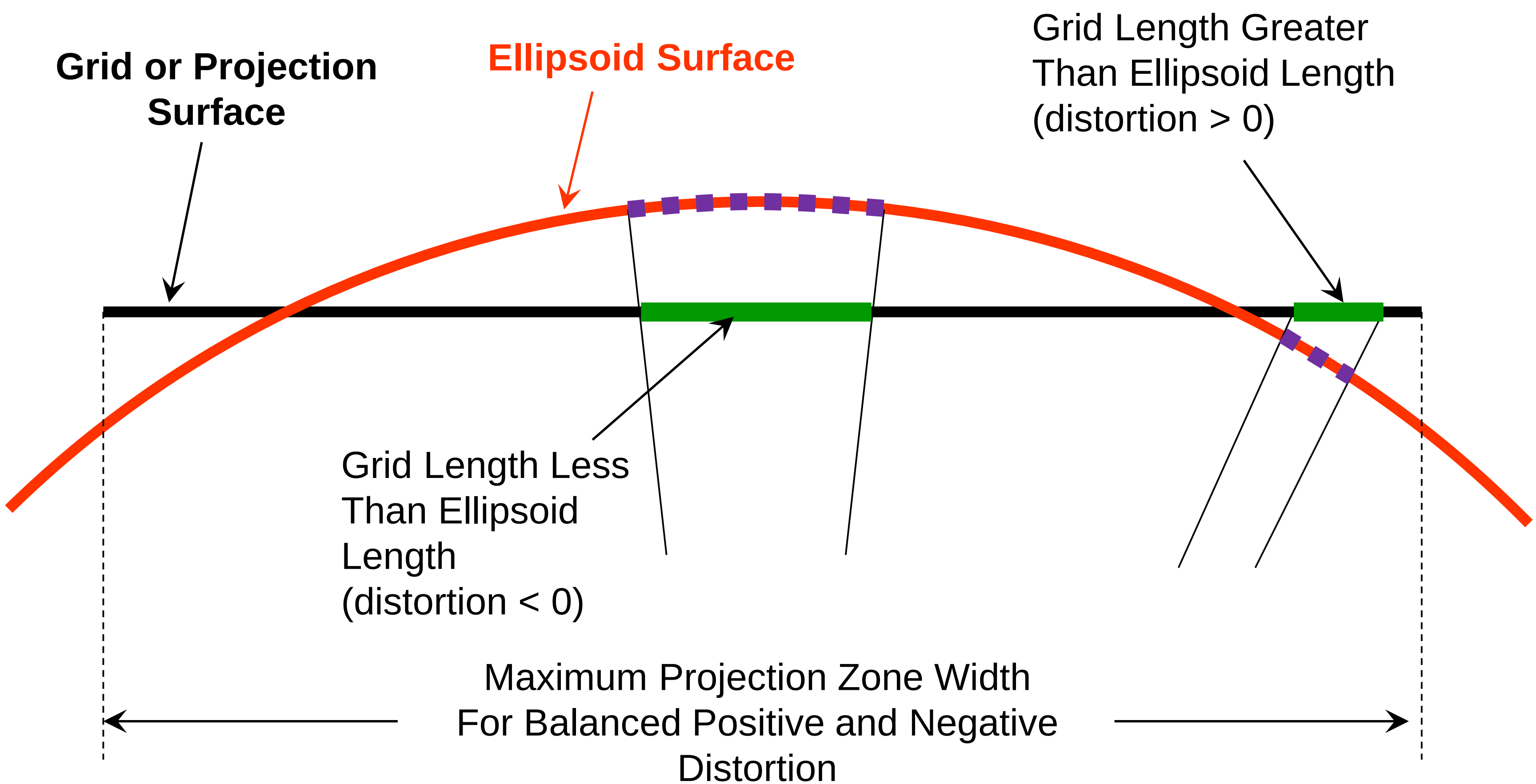
Zone Width (miles)	Maximum Linear Distortion		
	PPM	Feet/Mile	Ratio
16	+/- 1	+/- 0.005	1:1,000,000
50	+/- 10	+/- 0.05	1:100,000
71	+/- 20	+/- 0.1	1:50,000
112	+/- 50	+/- 0.3	1:20,000
158	+/- 100	+/- 0.5	1:10,000
317	+/- 400	+/- 2.1	1:2,500

Linear Distortion

- Difference in distance between a pair of **grid** coordinates when compared to the **ground** distance.
- Can be positive or negative
- Negative - grid length is **shorter** than ground
- Positive - grid length is **longer** than ground



Earth Curvature Factor



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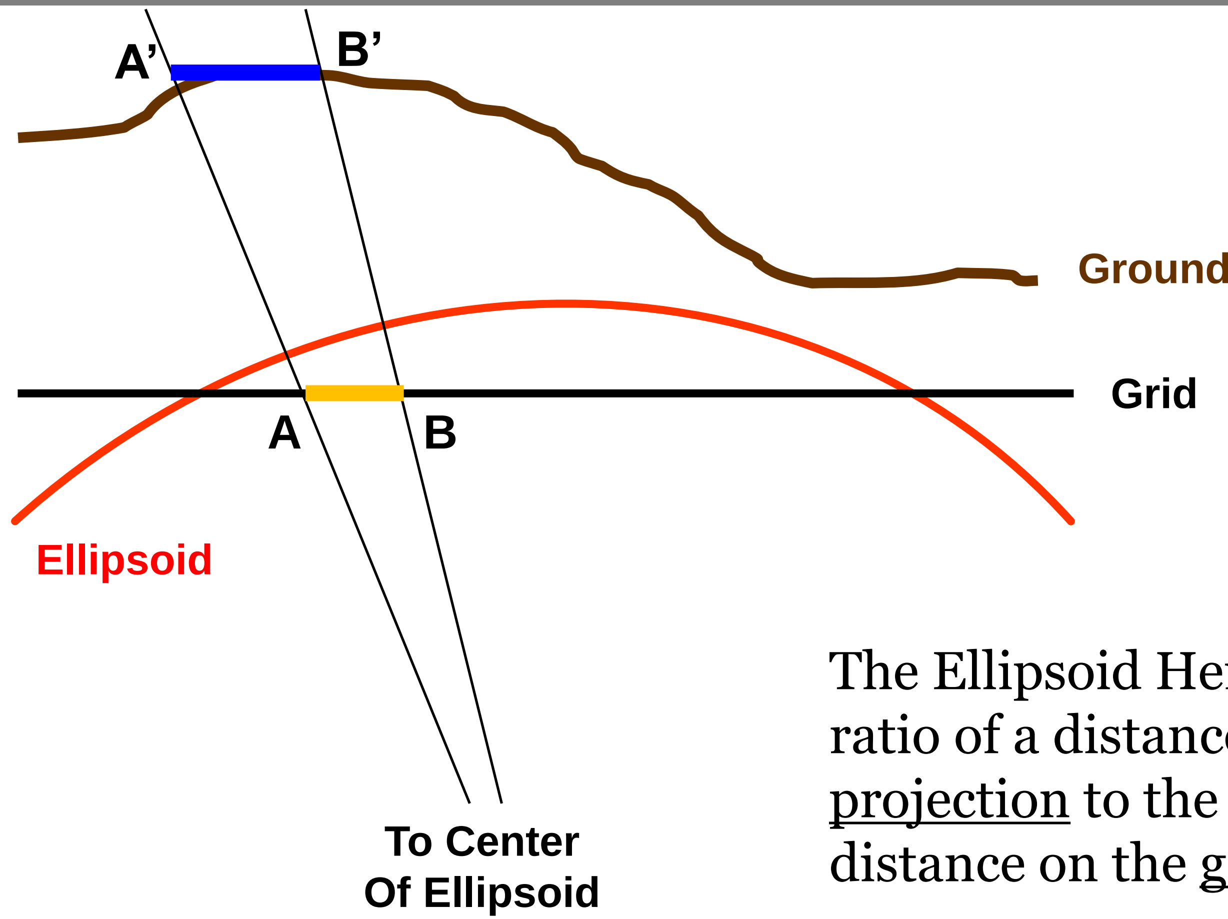
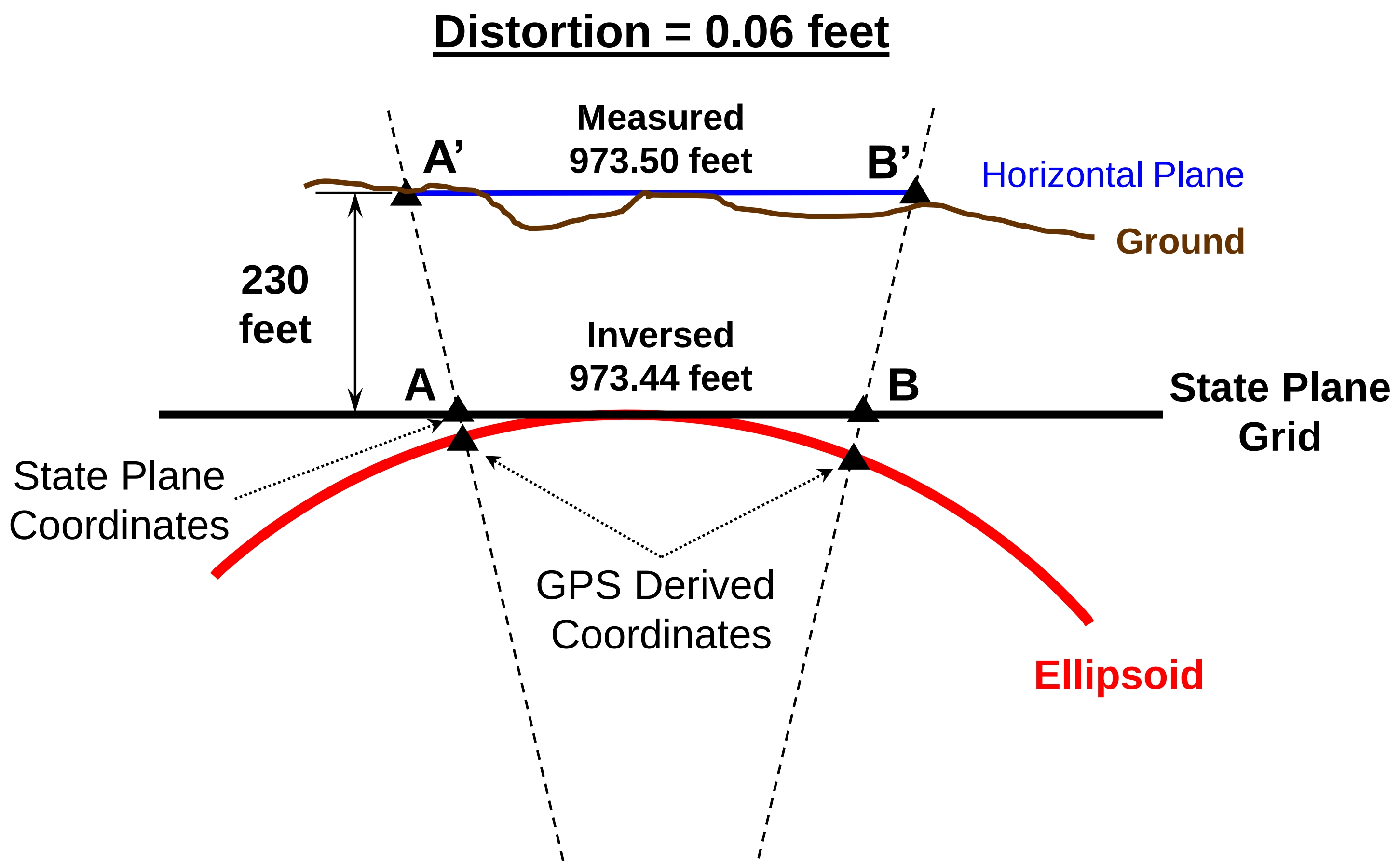
Ellipsoid Height Factor

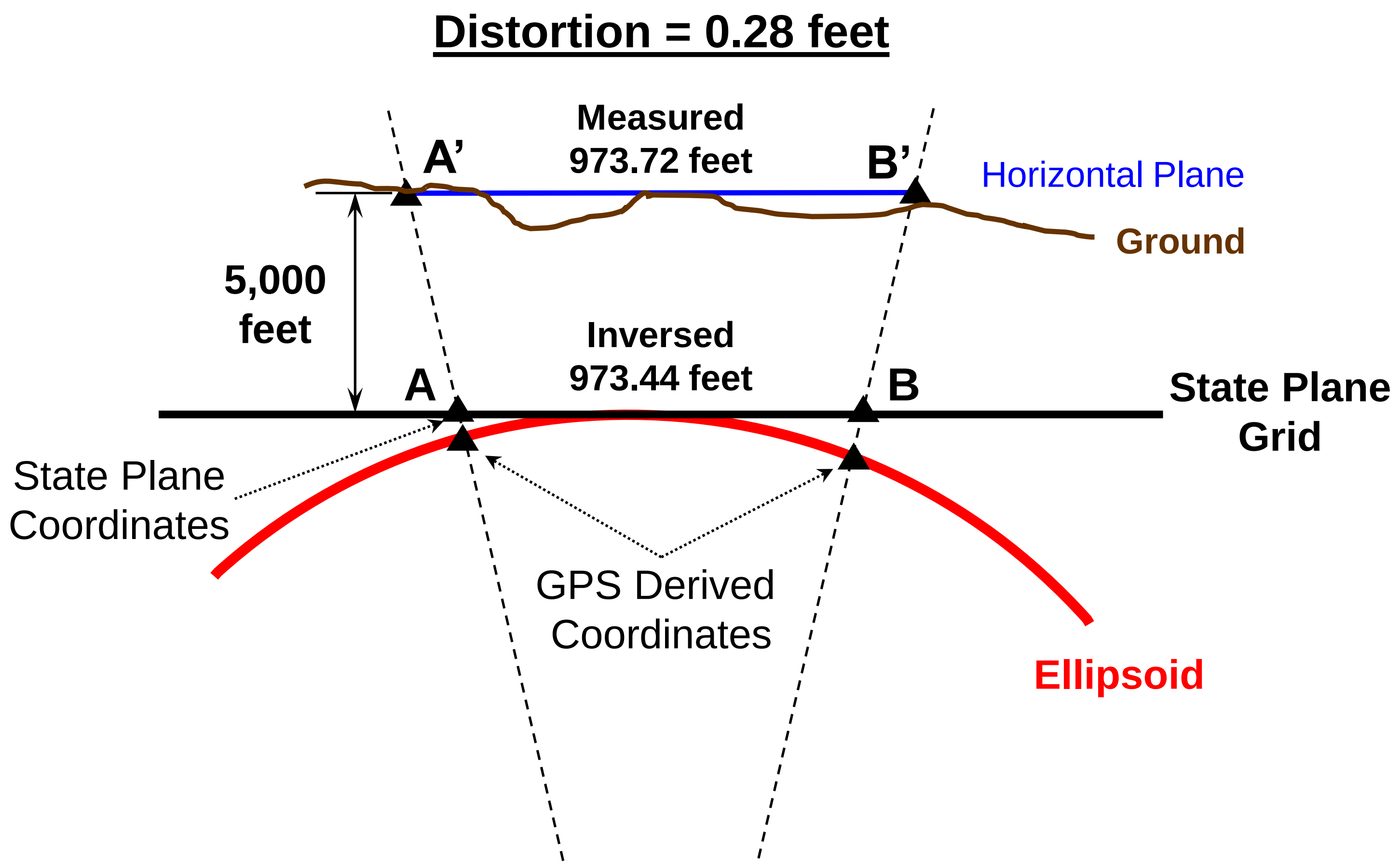


The Ellipsoid Height Factor is the ratio of a distance on the grid projection to the corresponding distance on the ground plane.

Distortion Due to Elevation



Distortion Due to Elevation

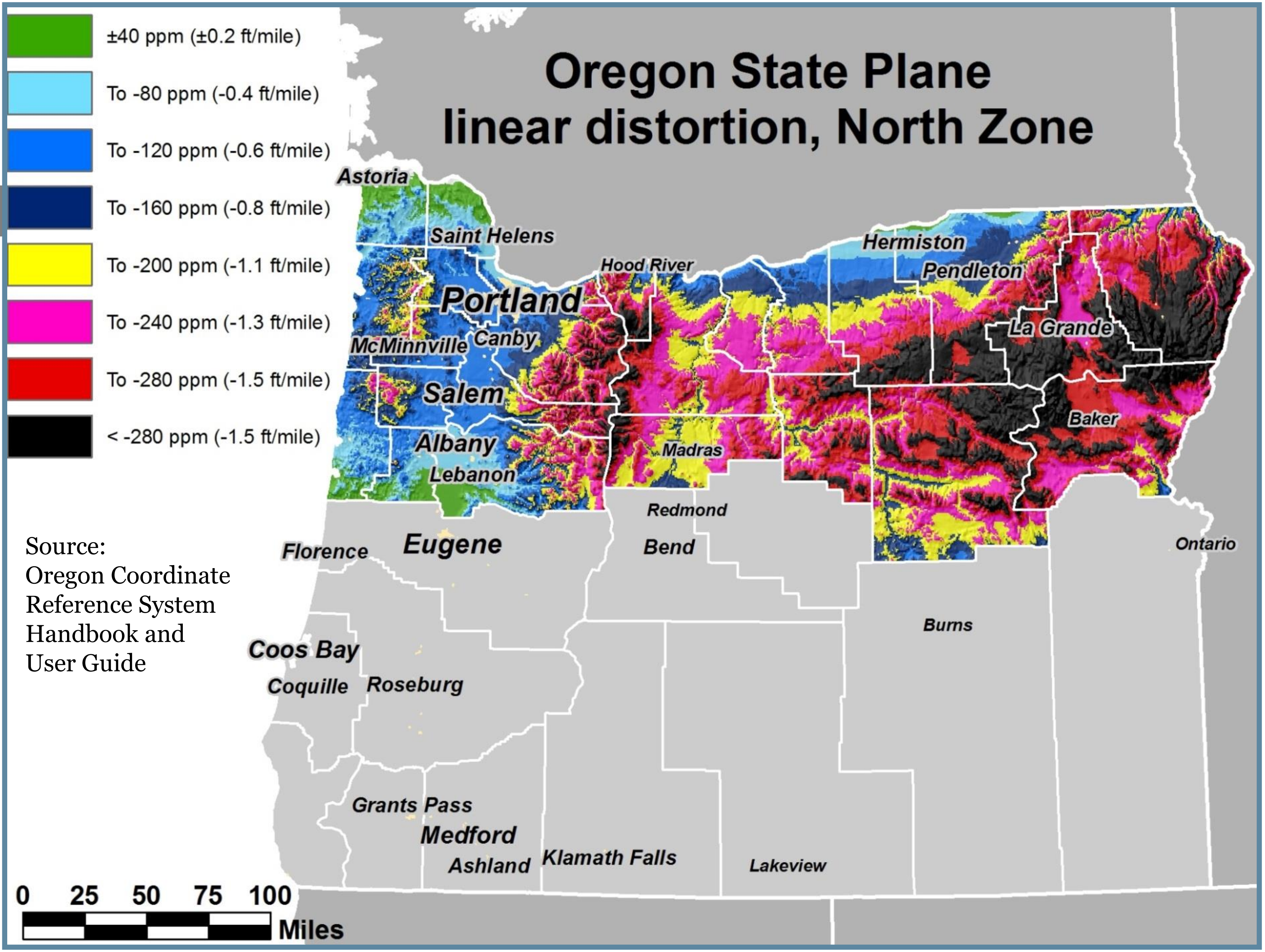


Distortion due to Height Above Ellipsoid

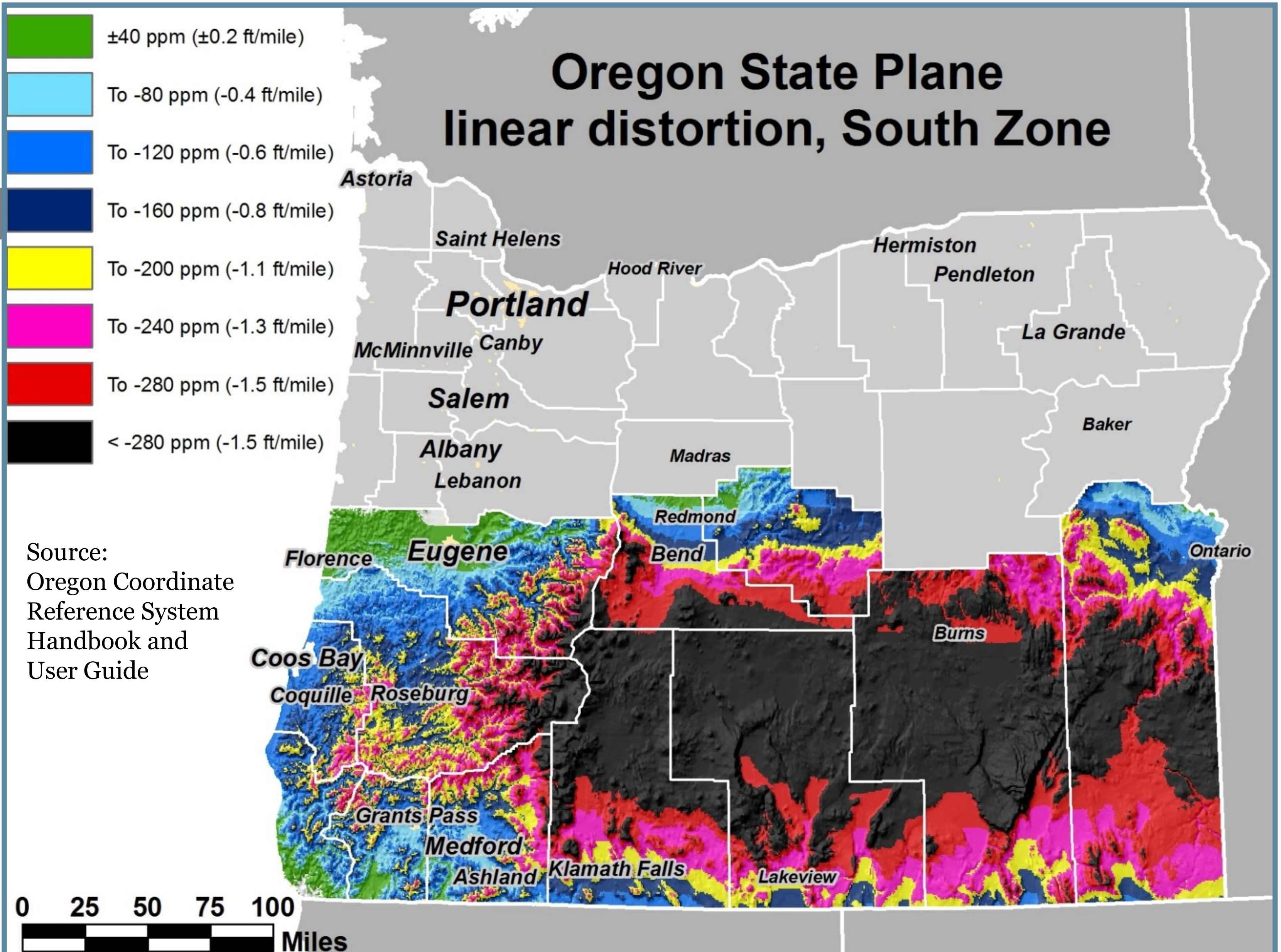
Height Above Ellipsoid (feet)	Maximum Linear Distortion		
	PPM	Feet/Mile	Ratio
100	4.8	0.03	1:209,000
400	19	0.1	1:52,000
1,000	48	0.3	1:21,000
2,000	96	0.5	1:10,500
4,000	191	1.0	1:5,200
7,000	335	1.8	1:3,000

Total Linear Distortion

- Combination of distortion due to earth curvature and height above ellipsoid
- Often, the distortion due to the height above the ellipsoid is greater than due to curvature



Source:
Oregon Coordinate Reference System Handbook and User Guide



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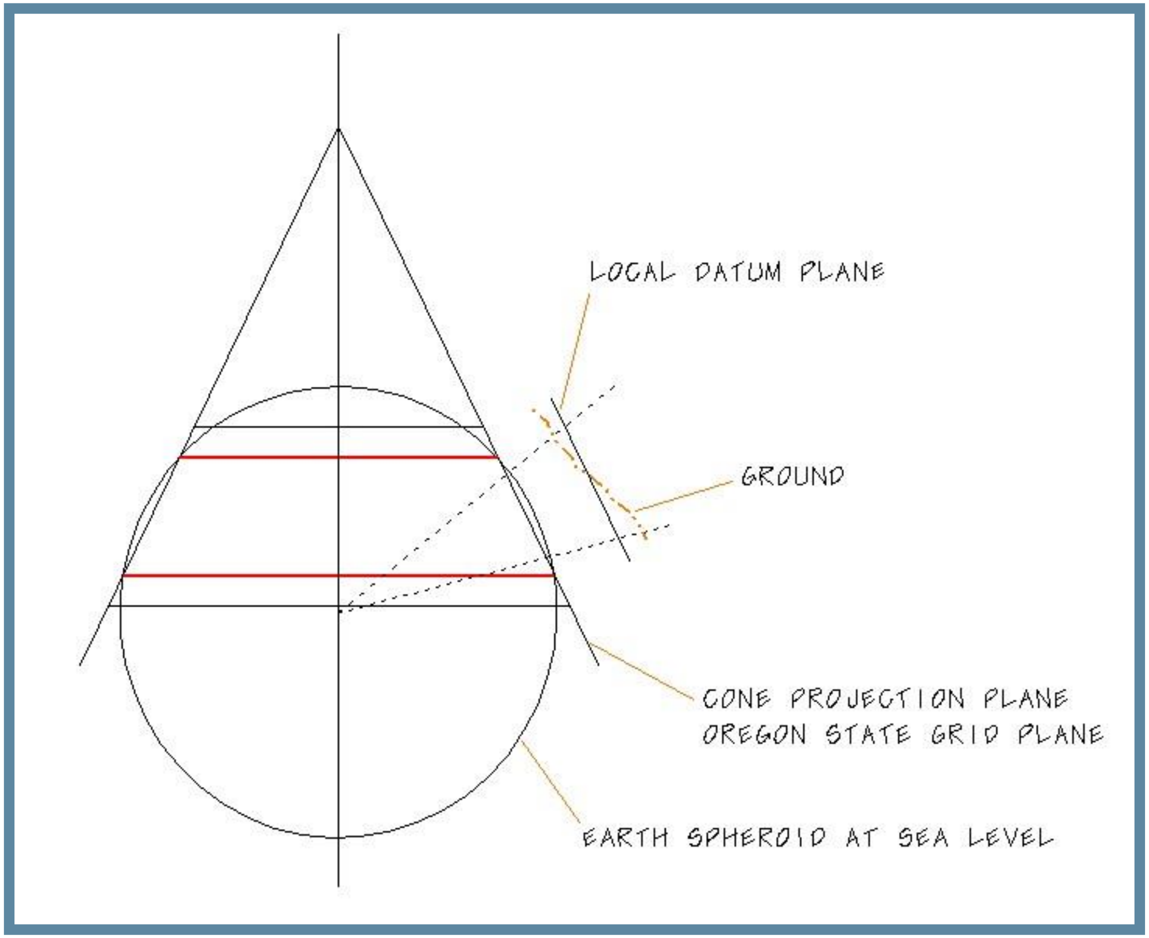
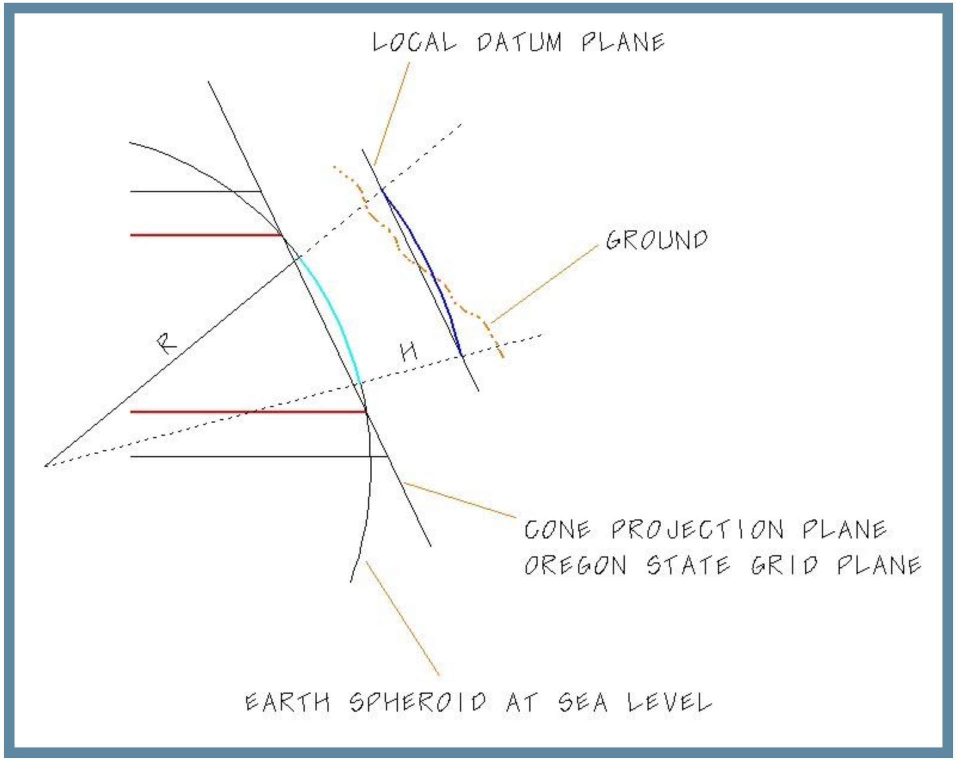
Local Datum Plane Coordinates



Developed by ODOT shortly after the implementation of the State Plane System

Local Datum Plane Coordinates

- Creates a plane close to the project elevation that is parallel to the State Plane grid
- Scaled by a Combined Scale factor
  - Projection factor
  - Height factor



Problems w/ scaling State Plane Coordinates

- Look too similar to State Plane Coordinates
  - Easy to confuse with State Plane Coordinates
- Metadata (scaling factor) documentation often separated from coordinate data.
- Unable to share data in geospatial software without scaling back to State Plane Coordinates.

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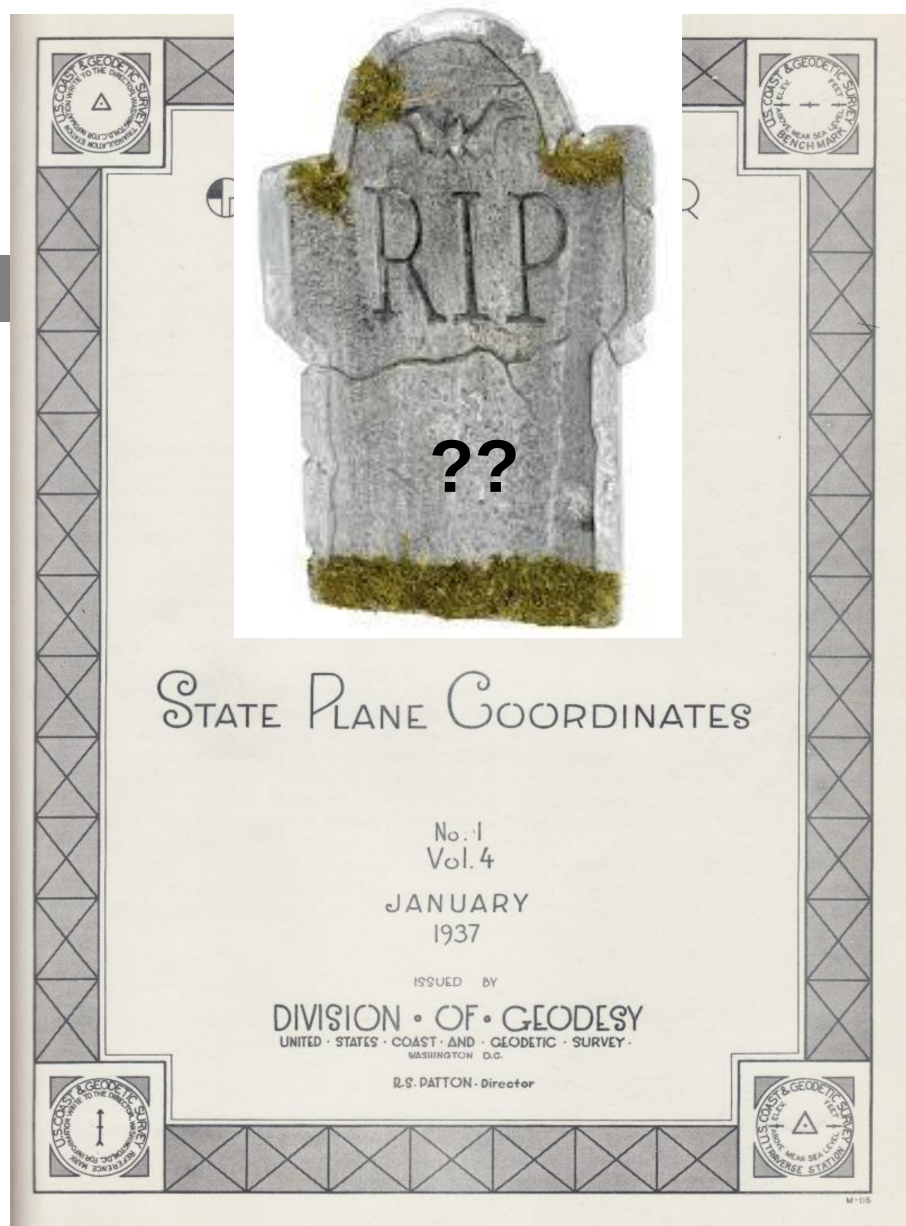
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BENCH MARK
TRAVERSE STATION

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/engautokeyconcepts.pdf

OREGON DEPARTMENT OF TRANSPORTATION

Highway Division

Authored and Presented by

Ron Singh, PLS
Geometronics Manager
Chief of Surveys
(503) 986-3033

Reviewed and Endorsed by

The Engineering Automation Steering Committee

Engineering Automation

Key Concepts for a 25 Year Time Horizon

8 March, 2009

Revision History

Authored by
Ron Singh, Geometronics Manager / Chief of Surveys

First Draft – 10 March, 2008
For review by the Engineering Automation Steering Committee

First Release – 21 April, 2008
Based on comments from the Engineering Automation Steering Committee

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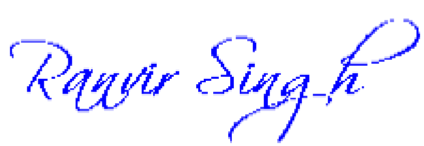
Second Release – 3 November, 2008
Added Executive Summary and made minor edits

Third Release – 8 March, 2009
Updated the status of Digital Signatures relating to new Oregon Administrative Rules.

Digitally Signed:



KEY CONCEPTS FOR THE FUTURE

DIGITAL DATA – CREATION, STORAGE, RETRIEVAL, AND FORWARD MIGRATION
MANAGING INFRASTRUCTURE LIFE CYCLE DATA
STRUCTURED DATA EXCHANGE - LANDXML
DIGITAL SIGNATURES
DATA SILOS
ENGINEERING DATA MANAGEMENT SYSTEM
ENGINEERING DATA AND ASSET MANAGEMENT
POST CONSTRUCTION SURVEYS
UNDERGROUND UTILITY LOCATION
DYNAMIC DOCUMENTS
ENGINEERING DATA AND THE GIS CONNECTION
IT INFRASTRUCTURE
WIRELESS COMMUNICATION
NEW STATEWIDE COORDINATE SYSTEM
THE OREGON REAL-TIME GPS NETWORK
HEIGHT MODERNIZATION
REMOTE SENSING
HIGH RESOLUTION IMAGERY/POINT CLOUDS FOR DESIGN
3D AND 4D DESIGN
VISUALIZATION
CONSTRUCTION AUTOMATION
MAINTENANCE AUTOMATION
ENGINEERING DATA AND INTELLIGENT TRANSPORTATION
DESIGN DATA AS PRIMARY AND CONSTRUCTION PLANS AS SECONDARY

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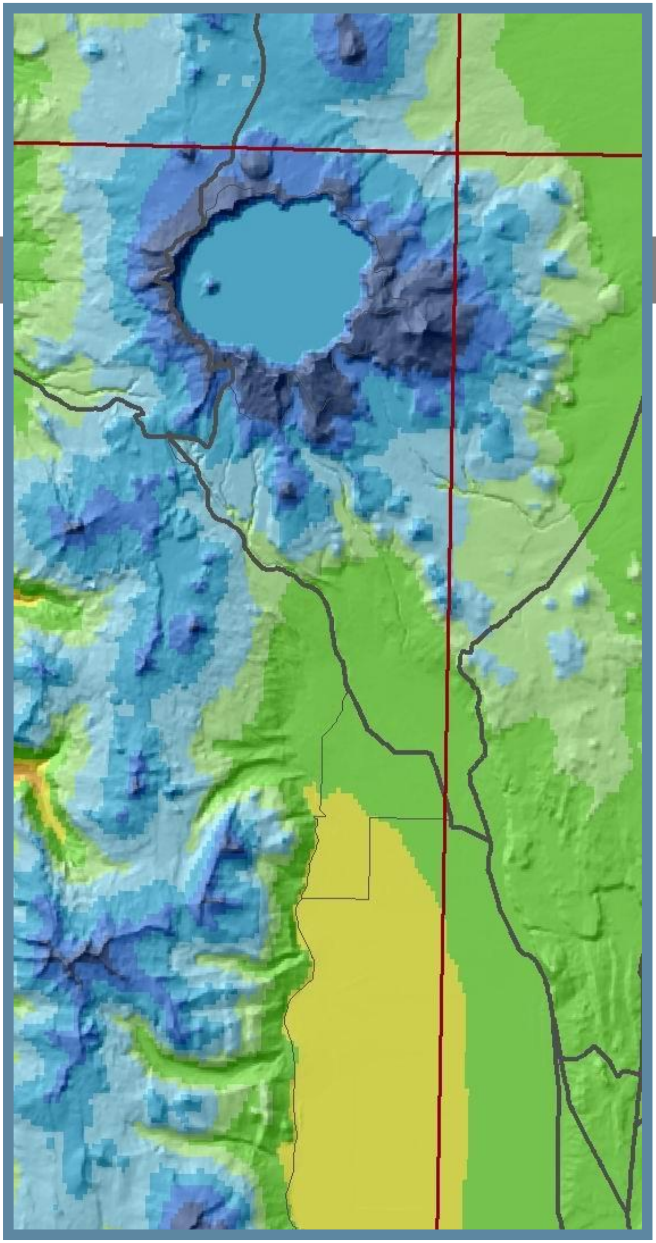
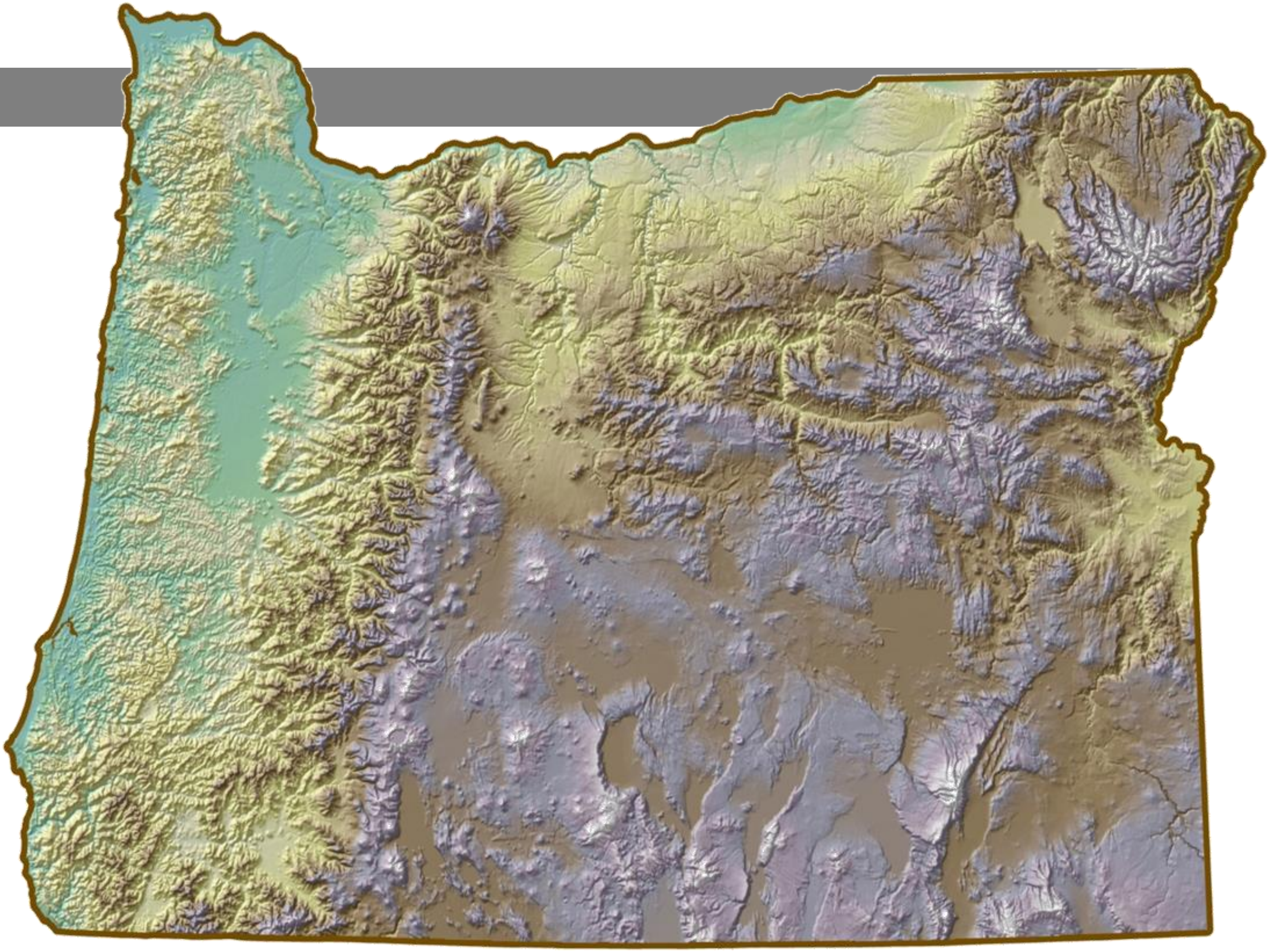


Low Distortion Projections

Low Distortion Projections

- Minimizes difference between “Grid” and “Ground”
- Central Meridian and Latitude near site, reducing distortion and Convergence Angle
- Well documented – easy to transform between LDP and National Spatial Reference System
  - Easily used in geospatial software to share data

Oregon Coordinate Reference System



O.C.R.S. History/Timeline

Mar. 2008	- Presentation to ODOT
July 2008	- Presentation to OGUG
Nov. 2008	- ODOT/OGUG Workshop
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Jan. 2012	- New OAR becomes effective

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OCRS Design Team

- Michael Dennis, PE, PLS, (GIS)
  - Private consultant: Geodetic Analysis
- Geospatial professionals from Oregon
  - ODOT
  - Private Surveyors
  - GIS professionals
  - Academia

Section 1.3: Best Practice Goals

- The Technical Development Team developed 21 “best practices” in an effort to focus on the critical elements that would be used to design the new low distortion OCRS mapping projections.

OREGON DEPARTMENT OF TRANSPORTATION

Highway Division
Geometronics Unit

Joseph Thomas, PLS
Geometronics Unit Manager/
Chief of Surveys

Mark L. Armstrong, PLS
NGS Northwest Region
Geodetic Advisor

Ken Bays, PLS
Lead Geodetic Surveyor
Geometronics Unit

Michael L. Dennis, RLS, PE
Geodetic Analysis, LLC

2017 Edition

Oregon Coordinate Reference System

Handbook and Map Set

Version 3.01 2-28-2017

Lead Author – Mark L. Armstrong

CONTAINS 39 OCRS ZONE MAPS

Combined Distortion Goals

PPM	Feet/Mile	Ratio
+/- 10	+/- 0.05	1:100,000
+/- 20	+/- 0.1	1:50,000

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PPM	Feet/Mile	Ratio
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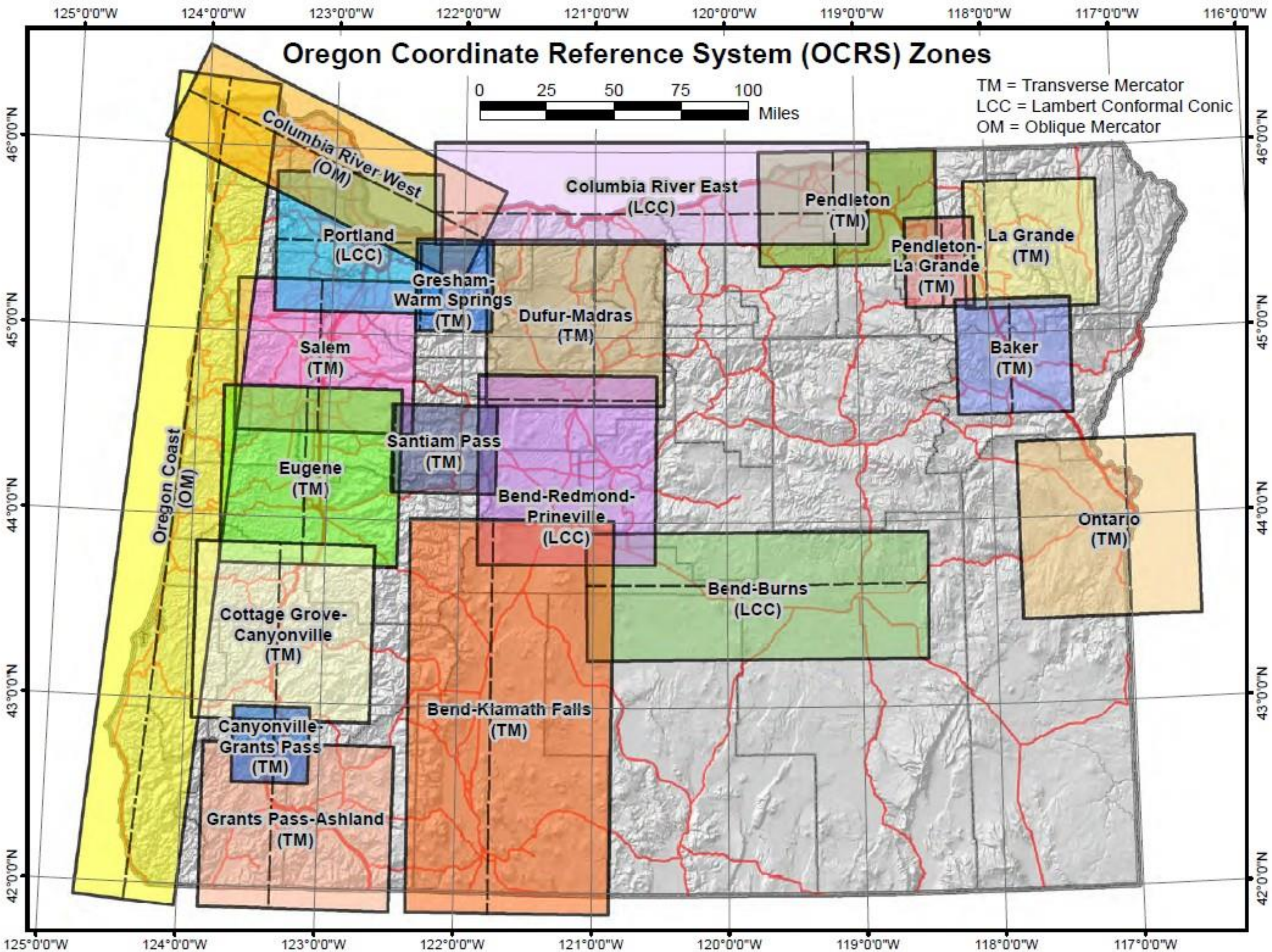
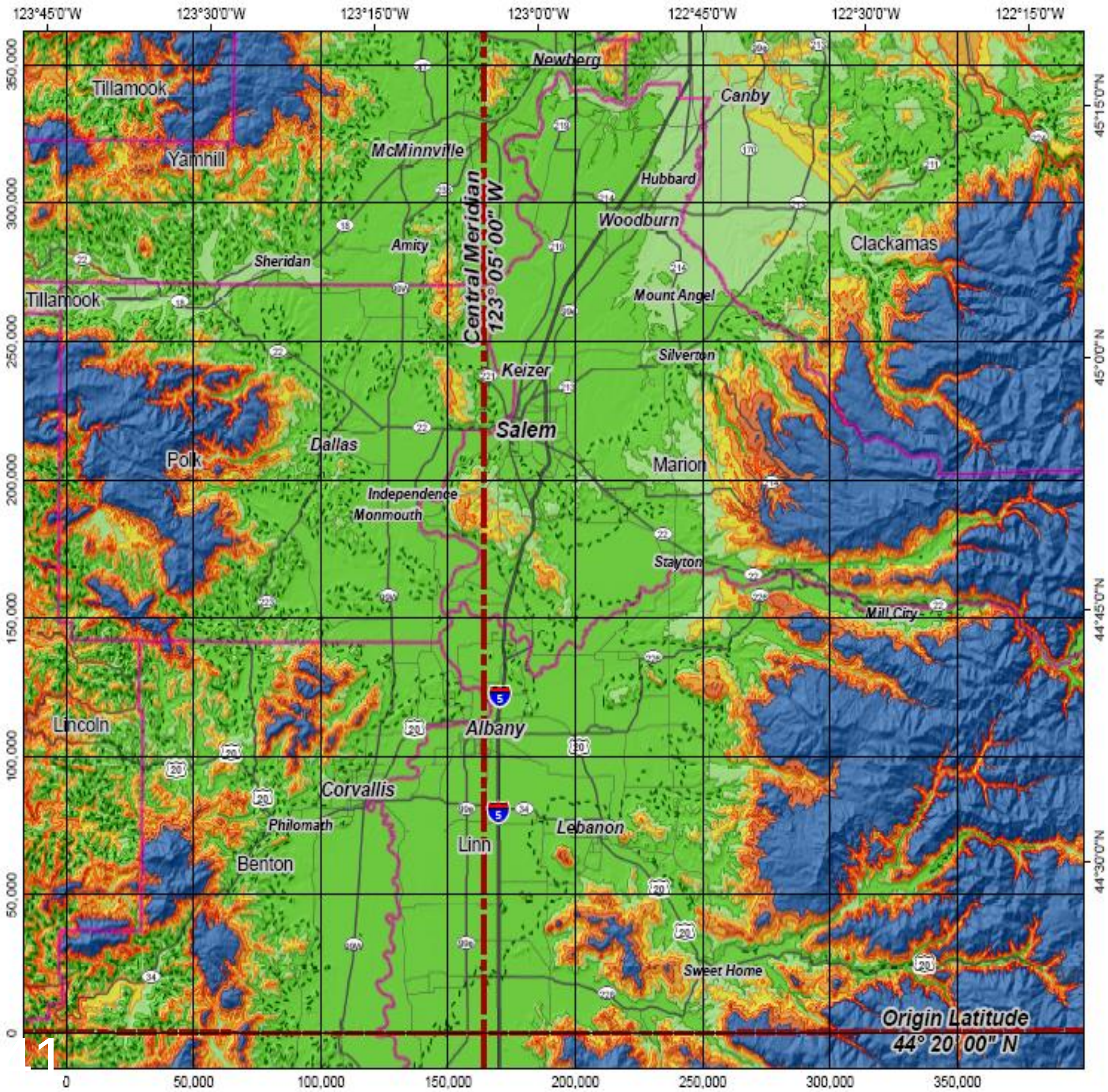

Oregon Coordinate Reference System (OCRS) Zones
0 25 50 75 100 Miles
TM = Transverse Mercator
LCC = Lambert Conformal Conic
OM = Oblique Mercator
Columbia River West (OM)
Columbia River East (LCC)
Pendleton (TM)
Pendleton-La Grande (TM)
La Grande (TM)
Portland (LCC)
Gresham-Warm Springs (TM)
Dufur-Madras (TM)
Salem (TM)
Baker (TM)
Oregon Coast (OM)
Santiam Pass (TM)
Eugene (TM)
Bend-Redmond-Prineville (LCC)
Ontario (TM)
Bend-Burns (LCC)
Cottage Grove-Canyonville (TM)
Bend-Klamath Falls (TM)
Canyonville-Grants Pass (TM)
Grants Pass-Ashland (TM)
125°0'0"W
124°0'0"W
123°0'0"W
122°0'0"W
121°0'0"W
120°0'0"W
119°0'0"W
118°0'0"W
117°0'0"W
116°0'0"W
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N



Oregon Coordinate Reference System

Salem Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	44° 20' 00" N
Central meridian:	123° 05' 00" W
False northing:	0.000 m
False easting:	50 000.000 m
Central meridian scale:	1.000 010 (exact)

Grid North

0 5 10 15 20 25 Miles

NOTE: Map grid is shown in units of international feet.

Linear distortion

- Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm (±0.05 ft/mi)
- 10 - 20 ppm (0.05 - 0.1 ft/mi)
- 20 - 30 ppm (0.1 - 0.15 ft/mi)
- 30 - 40 ppm (0.15 - 0.2 ft/mi)
- 40 - 50 ppm (0.2 - 0.25 ft/mi)
- > +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
Geodetic Analysis, LLC
8775 S Cliff Ranch Road
Pima, AZ 85543
mld@geodeticanalysis.com

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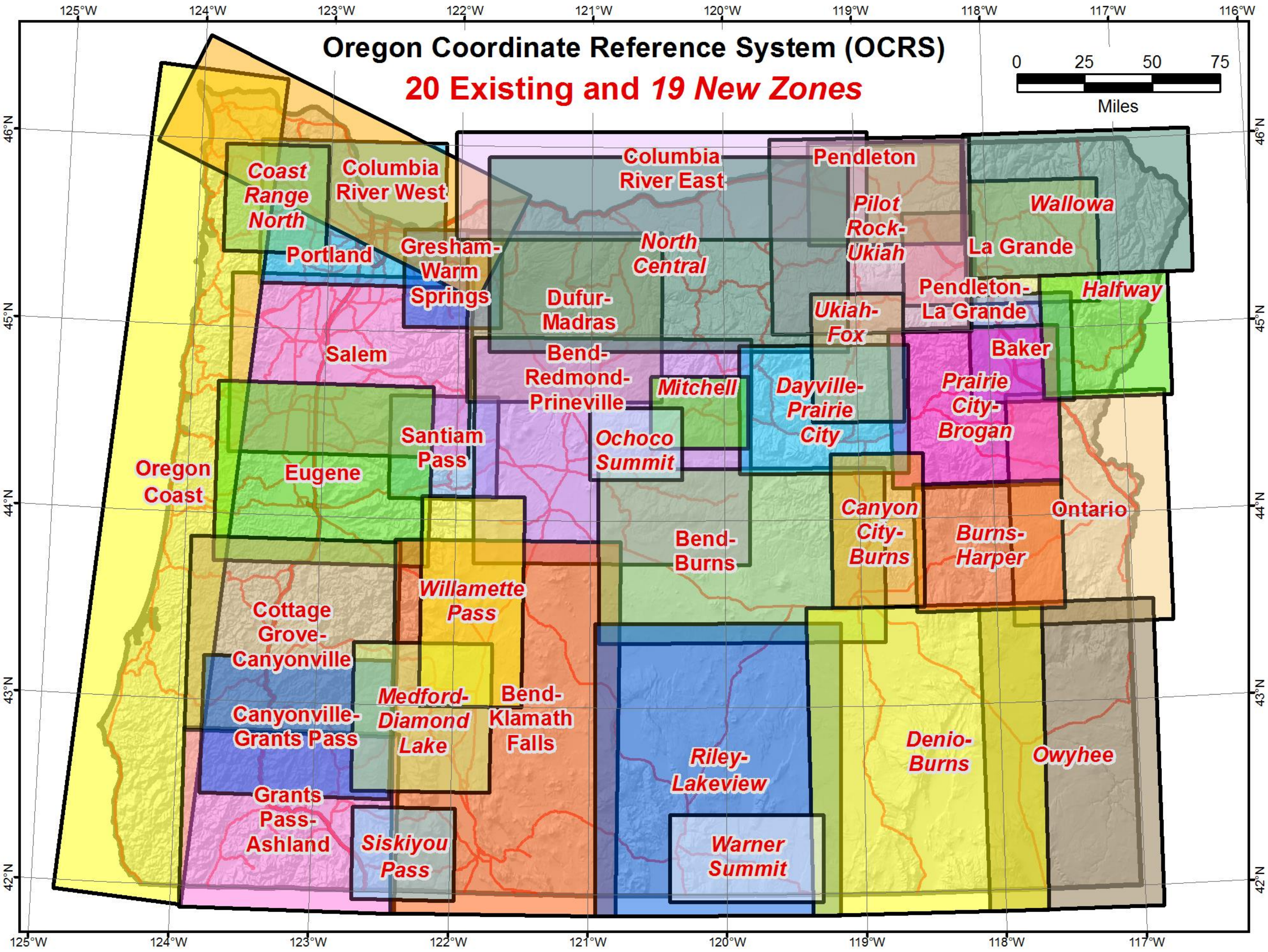
Dec 2011	-OTC approves OCRS OARs; OAR filed with Secretary of State
Jan. 2012	- New OAR becomes effective
2015-2016	**-19 additional OCRS zones designed to extend OCRS coverage**
Dec 2016	**-OTC approves the 19 additional zones.**

Oregon Department of Transportation

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/Pages/ocrs.aspx



Legal Status of OCRS

- The Oregon Transportation Commission adopted new Oregon Administrative Rules (OARs) defining the Oregon Coordinate Systems (734-005-0005, 734-005-0010, 734-005-0015) on December 21, 2011, and the rule was filed with the Secretary of State on December 22, 2011. **The rule became effective January 1, 2012.**

- These rules implement **Senate Bill 877** by moving all definitions of the existing Oregon State Plane Coordinate System from ORS Chapter 93 to ODOT's administrative rules and placing all definitions for the new Oregon Coordinate Reference System in the new OAR.

- Amended OAR adding 19 new OCRS zones was approved by the Oregon Transportation Commission in December 2016 and became effective in January 2017 when filed with Secretary of State.

► The Oregon Administrative Rules contain OARs filed through February 15, 2017 ◄

QUESTIONS ABOUT THE CONTENT OR MEANING OF THIS AGENCY'S RULES?
CLICK HERE TO ACCESS RULES COORDINATOR CONTACT INFORMATION

DEPARTMENT OF TRANSPORTATION, HIGHWAY DIVISION

DIVISION 5

OREGON COORDINATE SYSTEMS

734-005-0005

Purpose

The purpose of this administrative rule is to define the Oregon Coordinate System, consisting of three mapping projection coordinate systems that are authorized for use in the State of Oregon.

Stat. Auth.: ORS 184.616, 184.619, Ch.179 OL 2011
Stats. Implemented: ORS 209.130, 209.155, 209.250, 390.770, Ch.179 OL 2011
Hist.: HWD 13-2011, f. 12-22-11, cert. ef. 1-1-12

734-005-0010

Oregon Coordinate Systems

(1) The **Oregon State Plane Coordinate System of 1927** consists of two zones of mapping projections defined by the National Geodetic Survey of the National Ocean Service, one for the Oregon North Zone and one for the Oregon South Zone.

(2) The **Oregon State Plane Coordinate System of 1983** consists of two zones of mapping projections defined by the National Geodetic Survey of the National Ocean Service, one for the Oregon North Zone and one for the Oregon South Zone.

(3) The **Oregon Coordinate Reference System** consists of multiple zones developed by an Oregon Department of Transportation committee of private and public land surveying, geographic information system, and academic professionals to define a system of low distortion mapping projections wherein distances computed between points on the grid plane will represent the distances measured between the same points on the ground within published zone tolerances.

Stat. Auth.: ORS 184.616, 184.619, Ch.179 OL 2011
Stats. Implemented: ORS 209.130, 209.155, 209.250, 390.770, Ch.179 OL 2011
Hist.: HWD 13-2011, f. 12-22-11, cert. ef. 1-1-12

OAR 734-005

(3) Oregon Coordinate Reference System Zones.

(a) Baker Zone: [Table not included. See ED. NOTE.]

(b) Bend-Klamath Falls Zone: [Table not included. See ED. NOTE.]

(c) Bend-Redmond-Prineville Zone: [Table not included. See ED. NOTE.]

(d) Bend-Vale Zone: [Table not included. See ED. NOTE.]

(e) Canyonville-Grants Pass Zone: [Table not included. See ED. NOTE.]

(f) Columbia River East Zone: [Table not included. See ED. NOTE.]

(g) Columbia River West Zone: [Table not included. See ED. NOTE.]

(h) Cottage Grove-Canyonville Zone:[Table not included. See ED. NOTE.]

(i) Dufur-Madras Zone: [Table not included. See ED. NOTE.]

(j) Eugene Zone: [Table not included. See ED. NOTE.]

(k) Grants Pass-Ashland Zone: [Table not included. See ED. NOTE.]

(l) Gresham-Warm Springs Zone: [Table not included. See ED. NOTE.]

[ED. NOTE: Tables referenced are not included in rule text. Click here for PDF copy of table(s).]

(q) Pendleton-La Grande Zone: [Table not included. See ED. NOTE.]

(r) Portland Zone: [Table not included. See ED. NOTE.]

(s) Salem Zone: [Table not included. See ED. NOTE.]

(t) Sweet Home-Sisters Zone: [Table not included. See ED. NOTE.]

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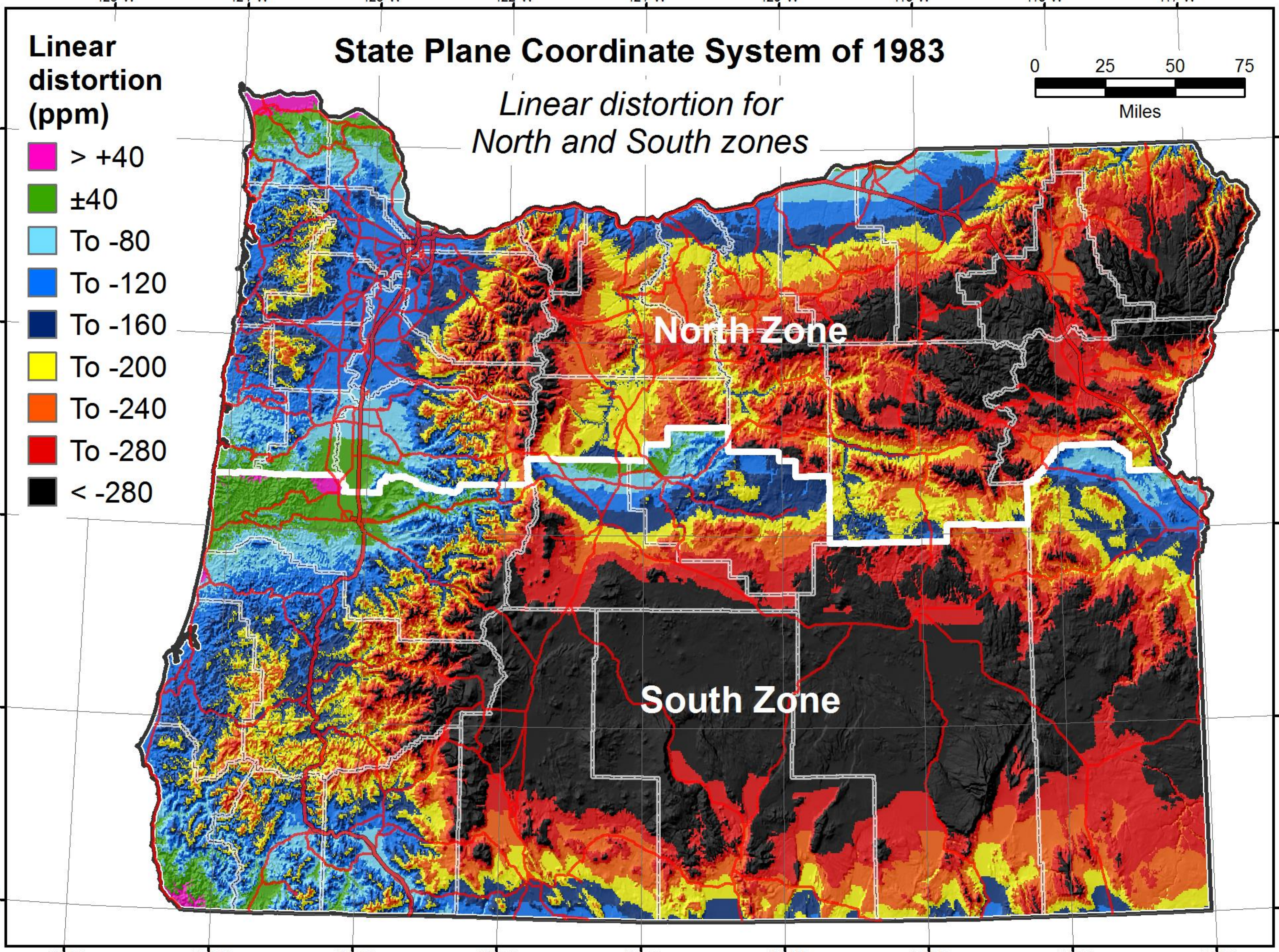
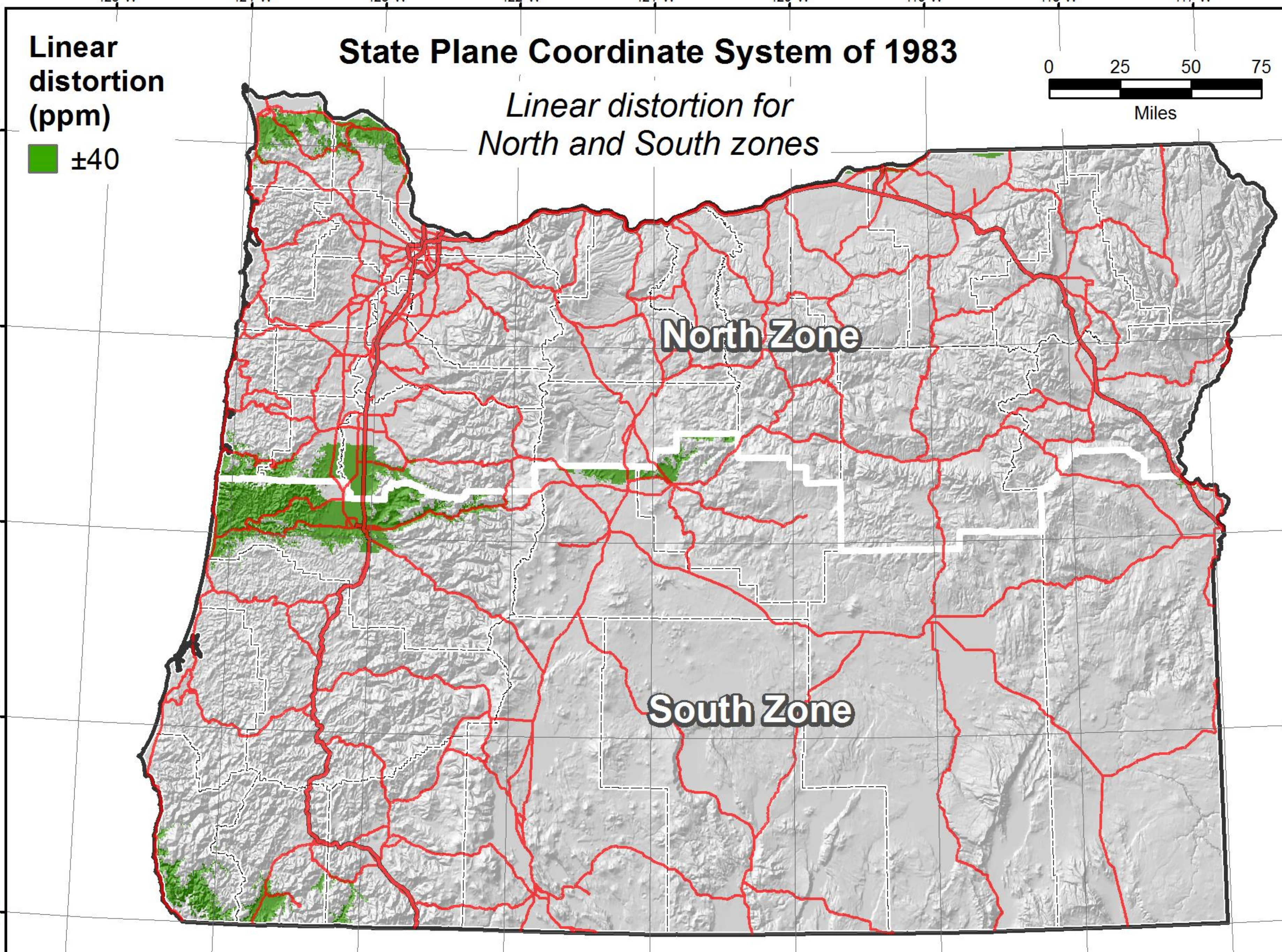
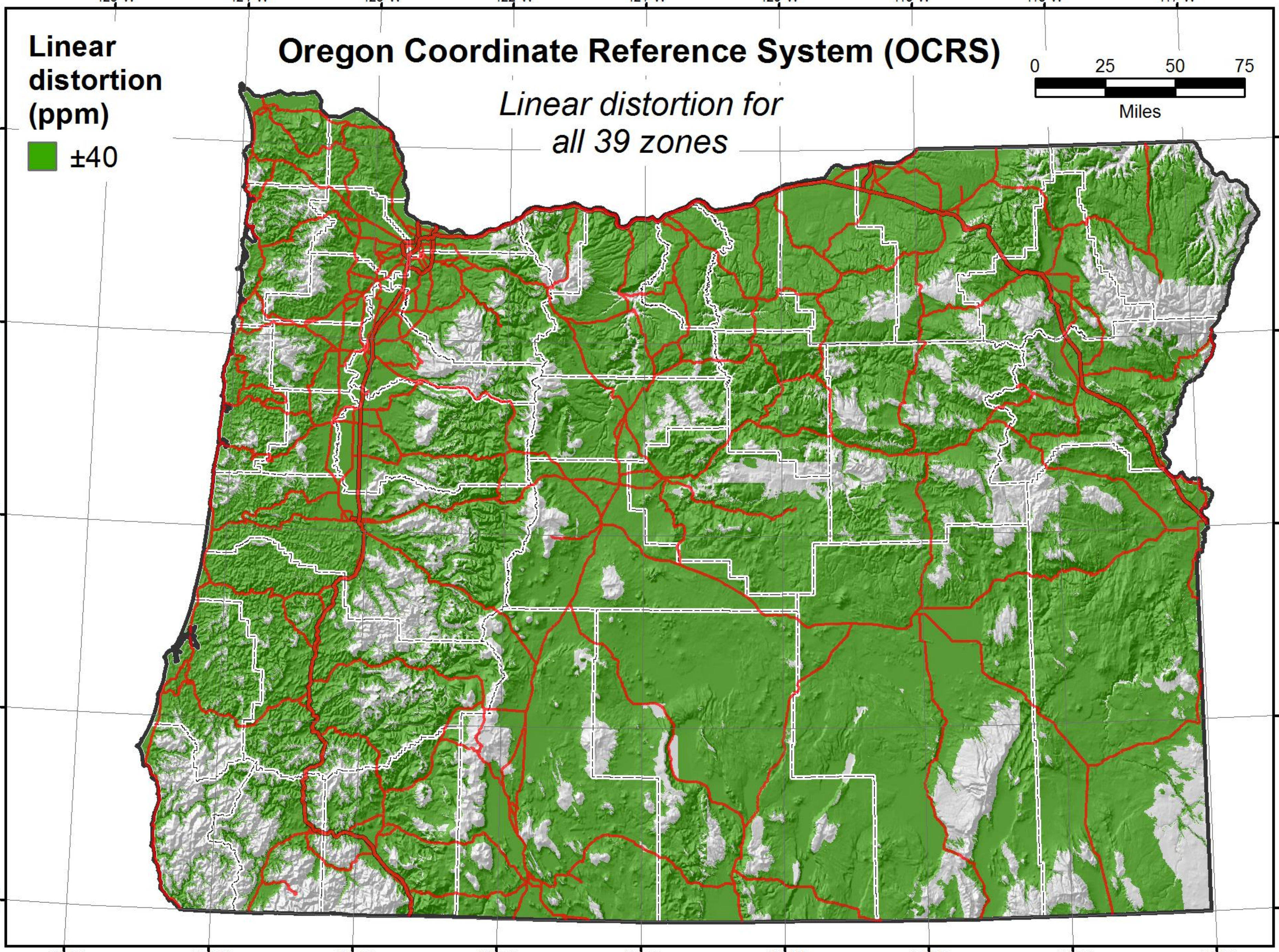


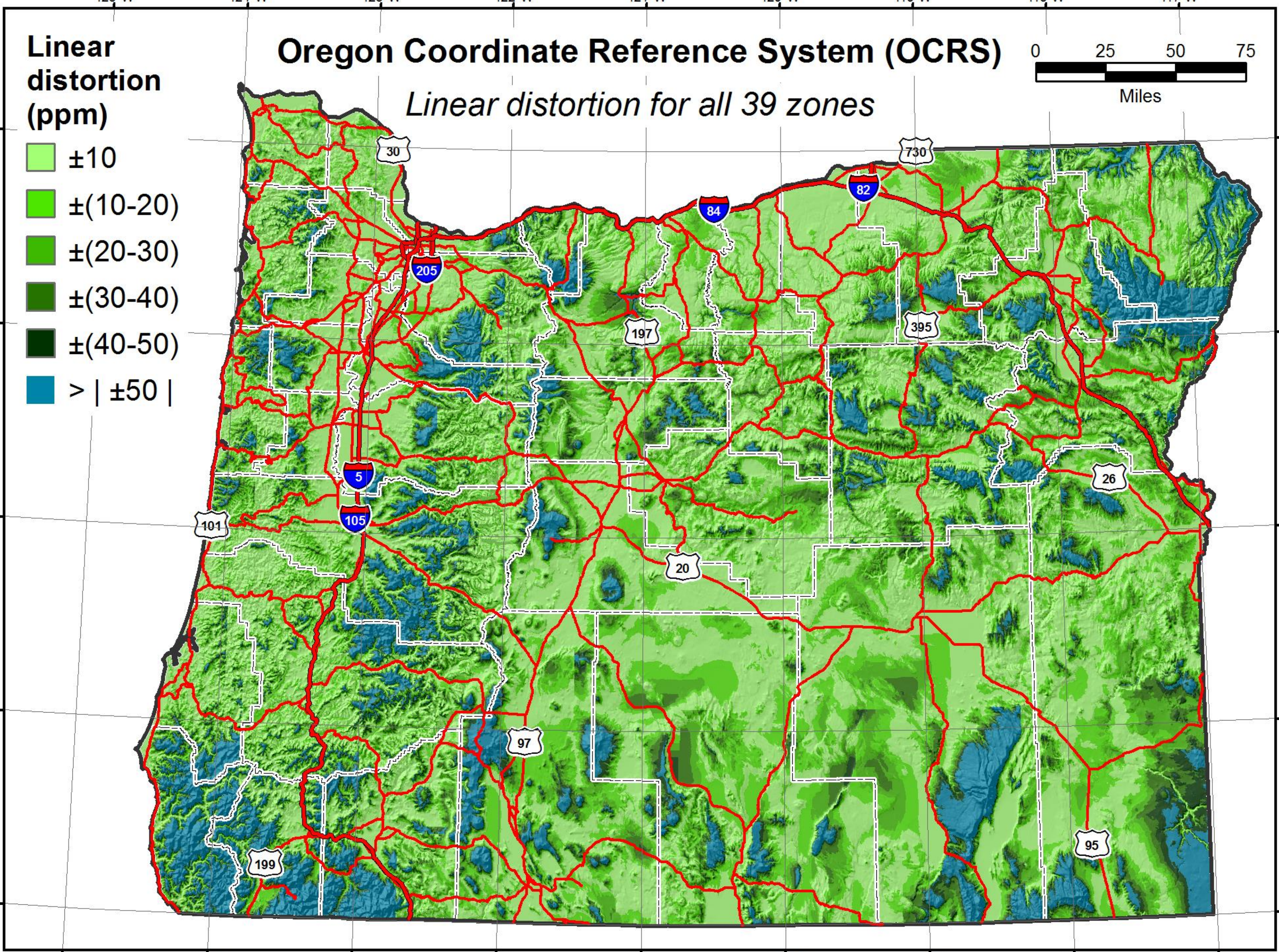
State Plane Coordinate System of 1983
Linear distortion for
North and South zones
Linear distortion (ppm)
> +40
±40
To -80
To -120
To -160
To -200
To -240
To -280
< -280
0
25
50
75
Miles
North Zone
South Zone
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N



State Plane Coordinate System of 1983
Linear distortion for
North and South zones
Linear
distortion
(ppm)
±40
0
25
50
75
Miles
North Zone
South Zone
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N



Oregon Coordinate Reference System (OCRS)
Linear distortion for all 39 zones
Linear distortion (ppm)
±40
0
25
50
75
Miles
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N



Oregon Coordinate Reference System (OCRS)
Linear distortion for all 39 zones
Linear distortion (ppm)
±10
±(10-20)
±(20-30)
±(30-40)
±(40-50)
> | ±50 |
0
25
50
75
Miles
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N
30
730
82
84
205
197
395
5
105
101
26
20
97
199
95

OCRS Website

Geometronics

Oregon Department of Transportation

Department

- Lists
- About Us
- Contact Us
- Benchmark Retrieval
- Geodetic Control
- ORGN (GPS Network)
- OCRS: OR Coord Ref Sys
- Links
- Manuals & Documents
- Maps & Plans Center
- Photogrammetry
- NGS OR Advisor
- Forms & Requests
- Right of Way Engineering
- Search Geometronics
- Survey Conference
- Survey Operations

Oregon Coordinate Reference System

- About the 'OCRS'
- History
- Legal Status
- OCRS Zone Maps
- OCRS Zone Export (Parameters)
- GIS Projection (.prj) Files
- Workshops & Presentations
- OCRS Handbook & User Guide
- GIS Interactive Map Tool
- Frequently Asked Questions

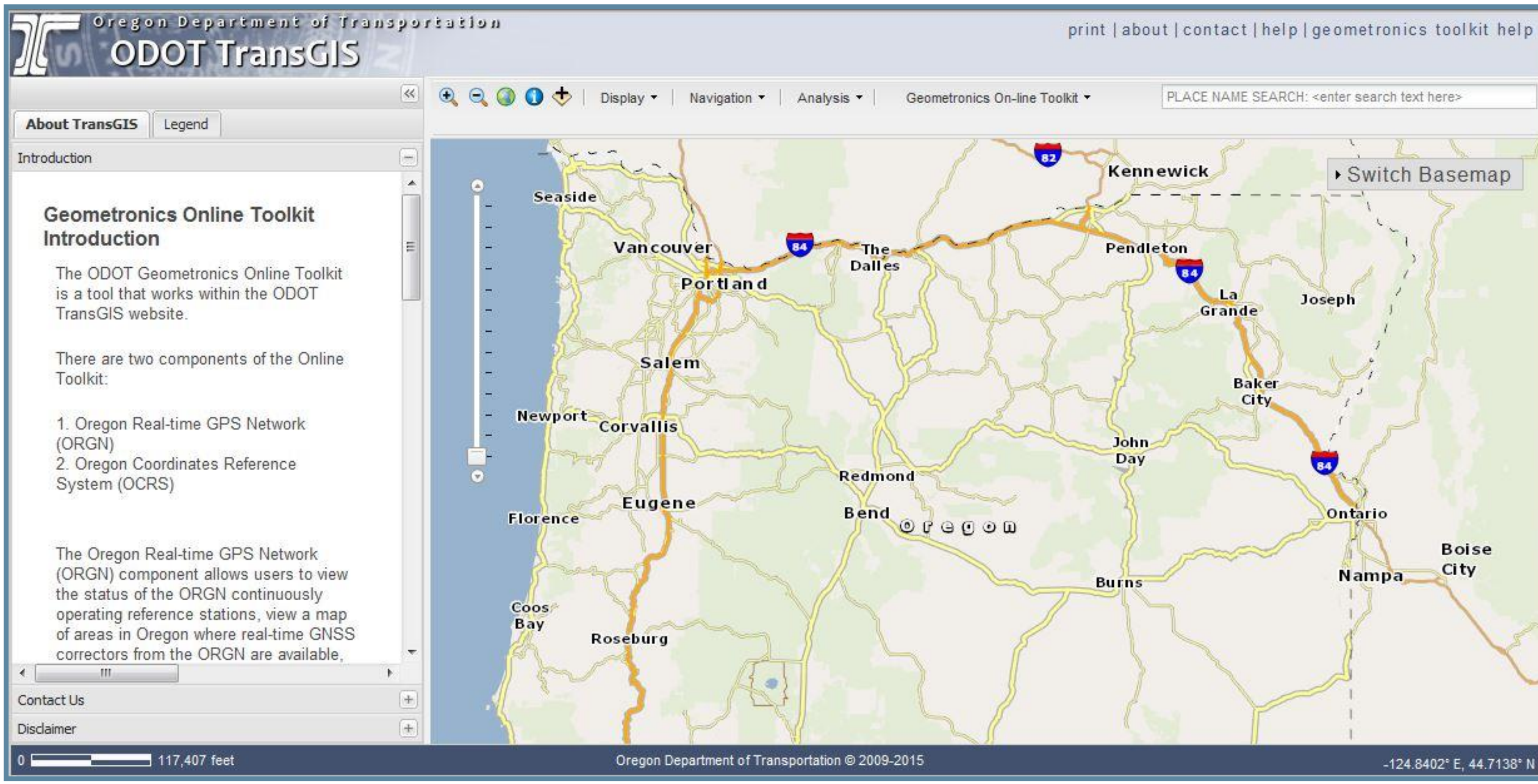
About the 'OCRS'

The Oregon Coordinate Reference System is based on a group of low distortion map projection coordinate systems. Low distortion projections are based on true conformal map projections designed to cover significant portions of urban and rural areas of the state. The term 'low distortion' refers to both the horizontal distortion from presenting a curved surface on a plane and the vertical distortion because these projections are also scaled to a regional height representative of the area to be covered. The advantages of a low distortion projection are;

- Grid coordinate zone distances closely match the same distance measured on the ground.
- Limited distortion and reduced convergence angle.
- Easy to transform between other coordinate zone systems.
- Maintains a relationship to the National Spatial Reference System (NSRS). Can cover entire cities and counties making them GIS friendly.

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/Pages/ocrs.aspx

Geometronics On-line Toolkit



https://gis.odot.state.or.us/geometronicsonlinetoolkit/

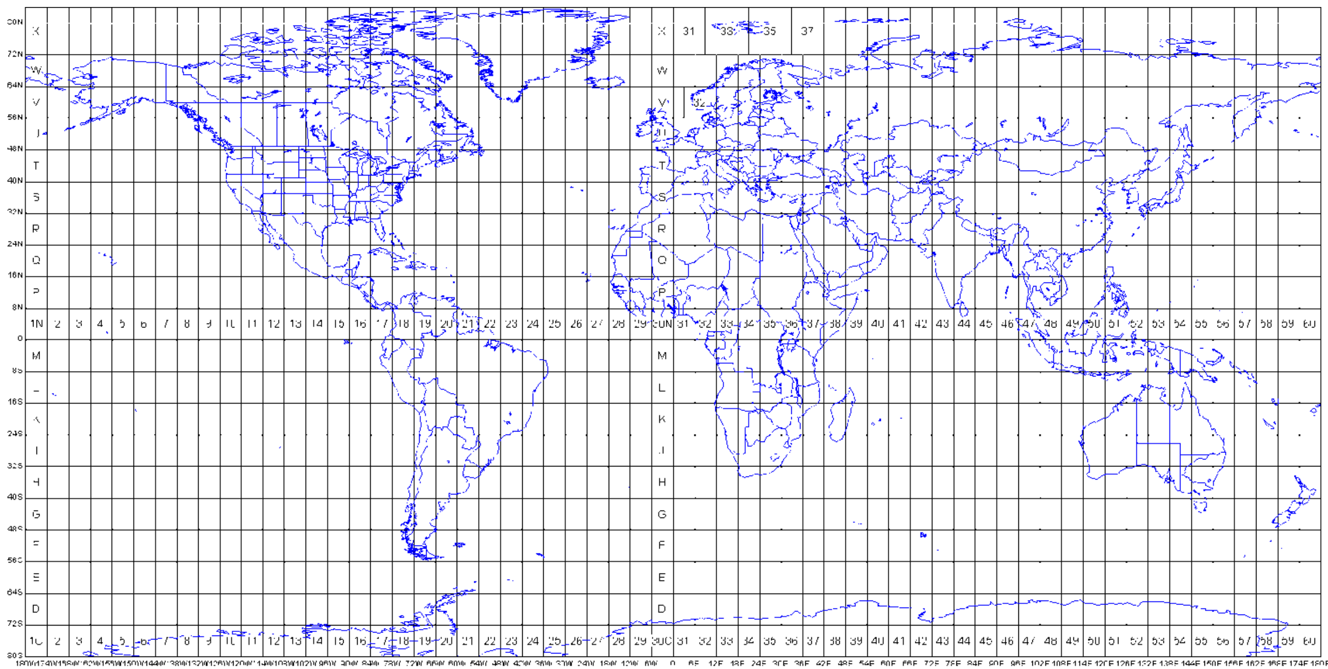
Summary

- Why the OCRS was developed. What was the need?
- Best practices used to design the OCRS
- Path & timeline to develop the OCRS
- Distortion maps: the original 20 and the 19 new OCRS zones

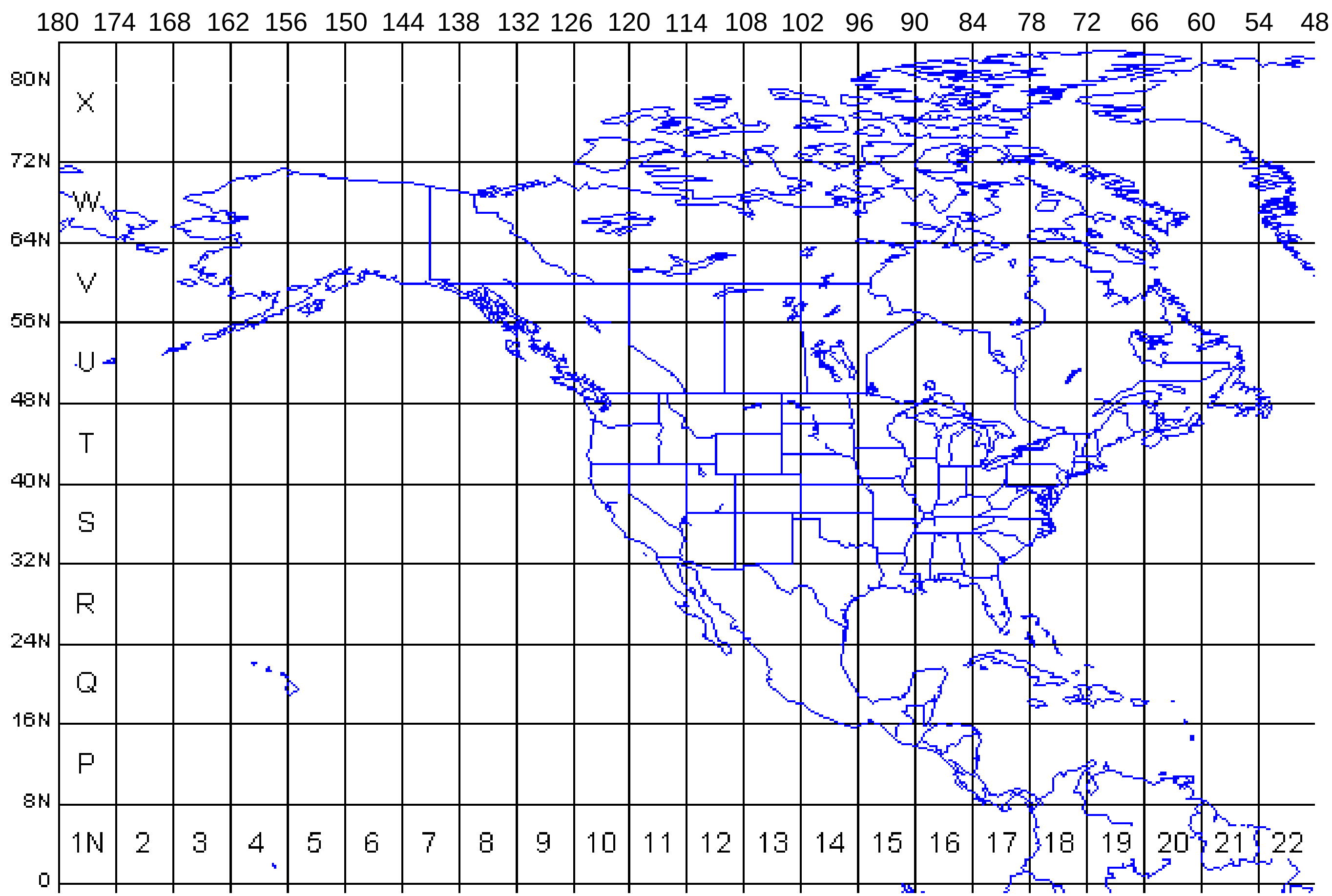

Adios, amigos!

Universal Transverse Mercator (UTM Coordinate System)

World wide coordinate system which employs 60 zones, commencing at 180 degrees West longitude, each of which embraces 6 degrees of longitude and lies between 84^{o} North and 80^{o} South latitudes.



UTM Zones in North America

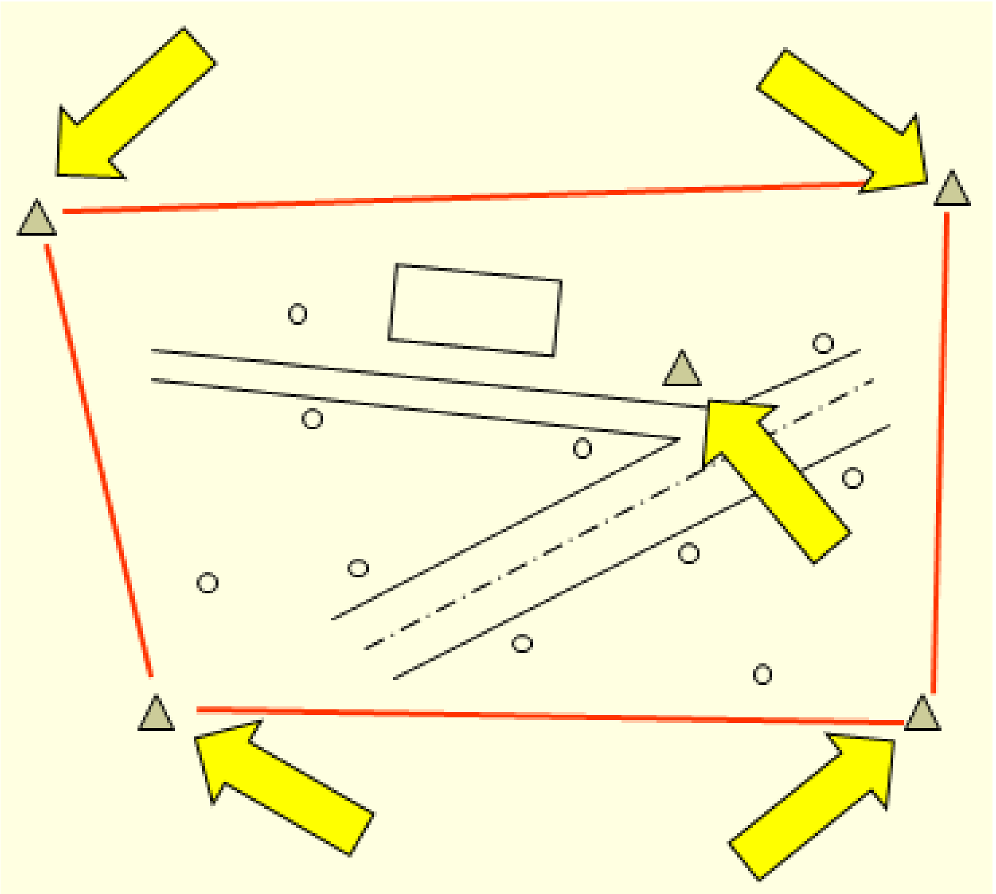


Site Calibration

- Known by several names … localization, transformation
- Each manufacturer or software has unique procedures, methods, reports, etc.
- Common theory between all brands… Calibrate to points that are within or surround the project which have known control coordinates in the local system.

Site Calibration

- Calibrate to points that surround the project that have coordinates known in the local system.
- Occupy calibration points with GPS while receiving real-time correctors from the ORGN, then calibrate to the local system.



Site Calibration Example

Occupy known control points with the GPS Rover while receiving real-time correctors from the ORGN, then calibrate the World system to your local system using the on-board or office software.