Best Practices for Developing Low Distortion Projections

Montana Association of Registered Land Surveyors 2012 Conference

65 Slides

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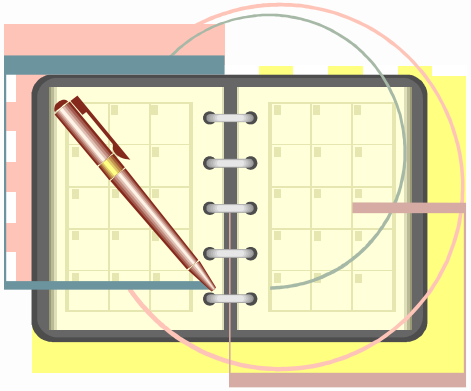
Topics

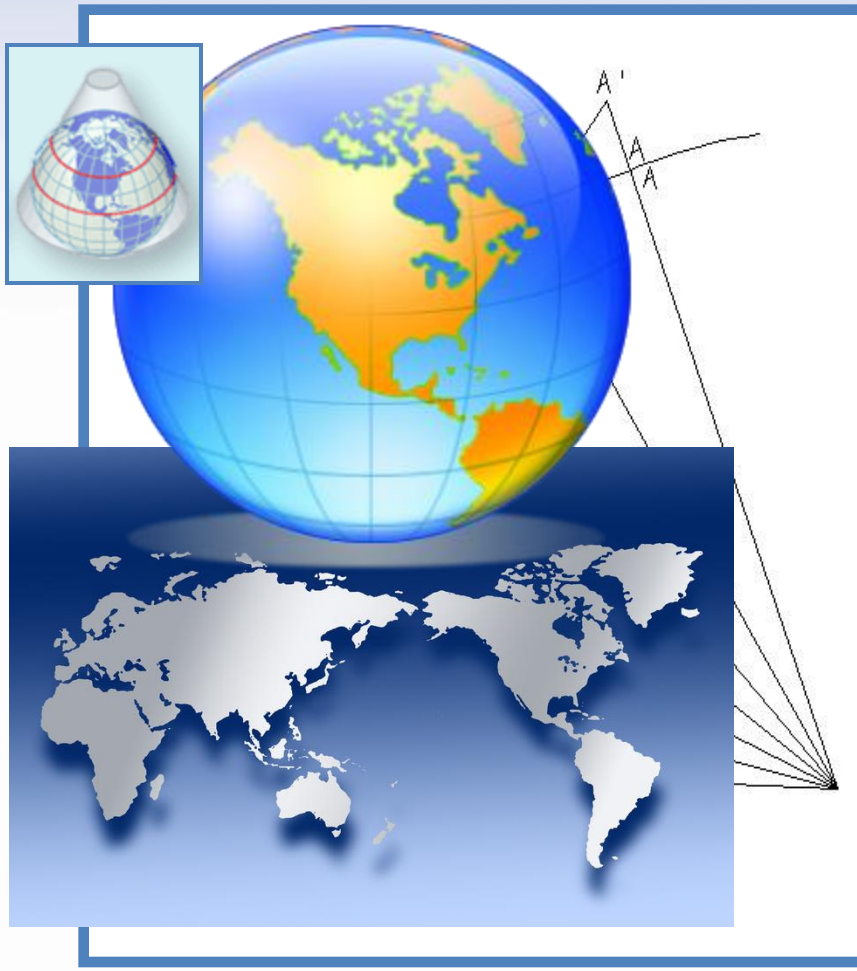
- Map Projection Basics
- How are LDPs different from State Plane?
- Local Datum Plane Coord. Vs LDP Coord.
- Putting LDPs to Work on your Project
- The Surveyor's Emerging Role
- Questions



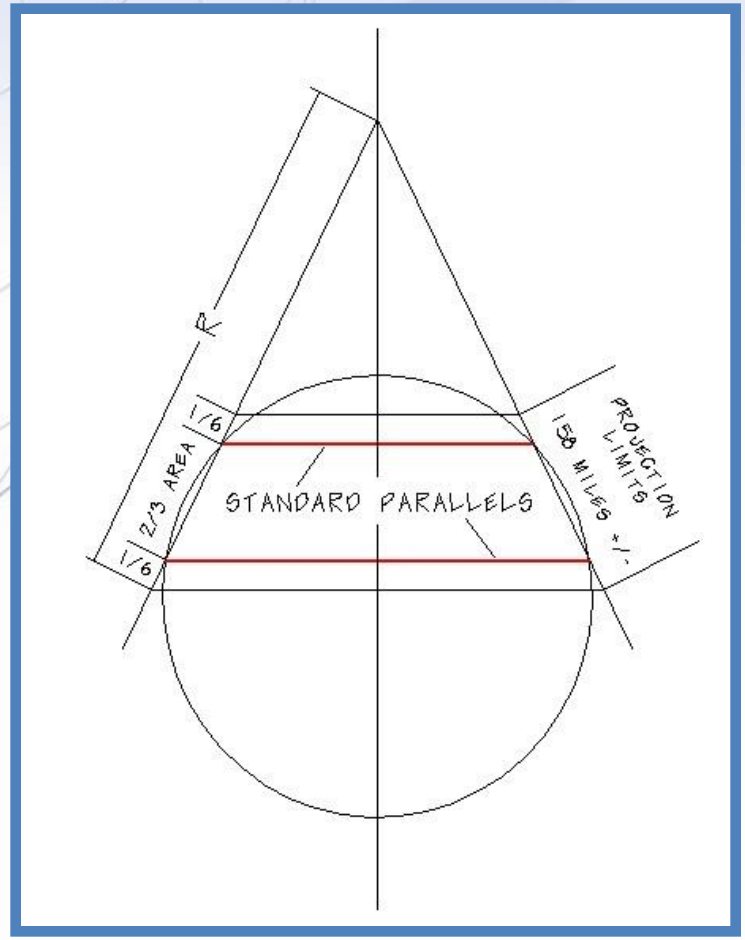
Map projections are necessary

- BUT…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.



State Plane Coordinate System



Developed by USC&GS in 1933 at the request of an engineer from the North Carolina Highway Department.

State Plane zones have been around a long time and they are still used but now realized as perhaps not the best map projection solution for a given topography above sea level.

Oregon State Plane Coordinate System is typical to many other states

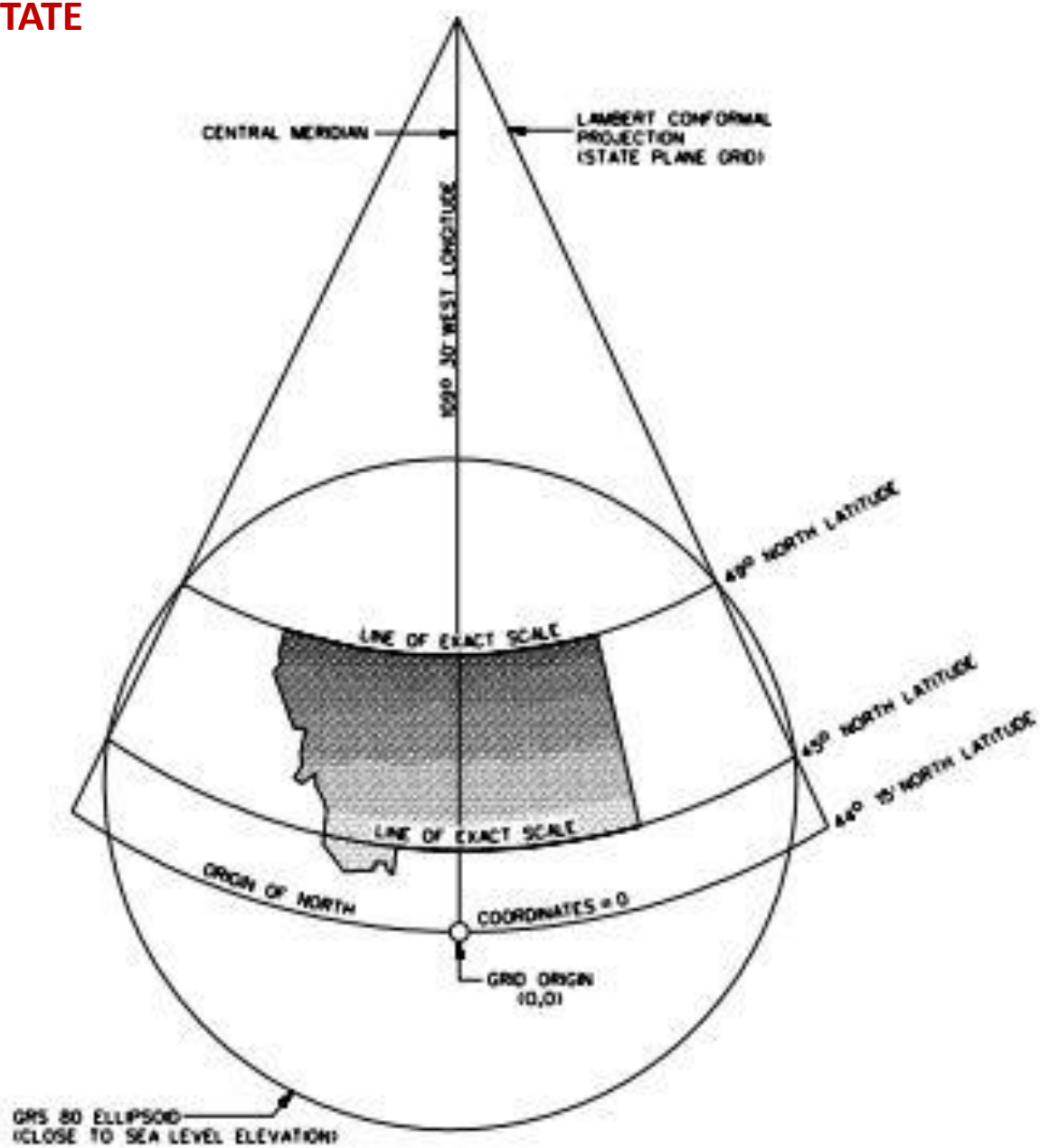
- Developed by USC&GS in 1938
- Given legal status in 1945
- Lambert Conformal Conic Projection
- 2 zones
- With 2 parallels – secant projections
- 158 miles wide
- Maximum projection distortion design 1:10,000 (reasonable for surveying prior to EDM and GPS)
- No consideration for distortion by height

Montana State Plane Coordinate System

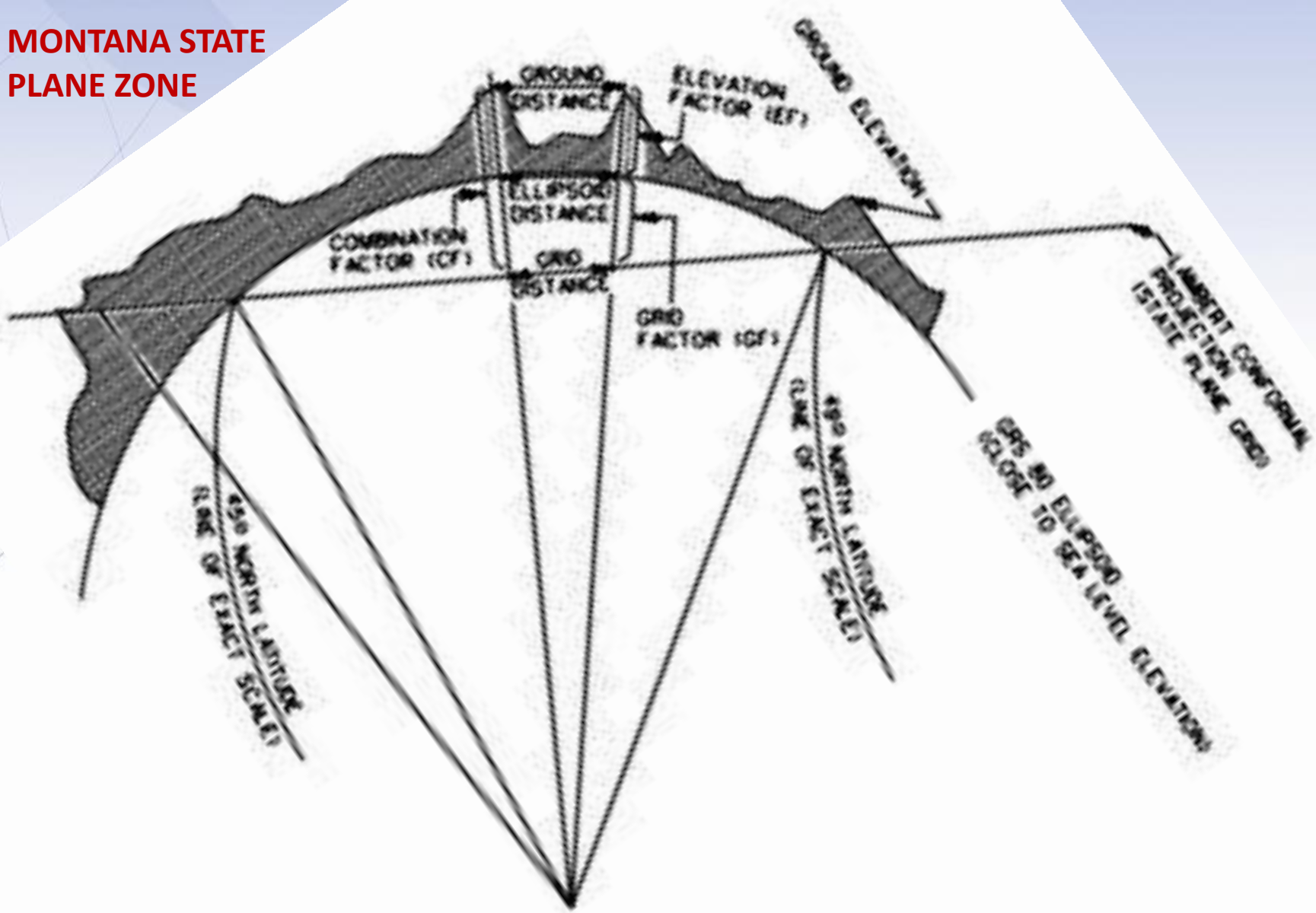
Montana State Plane Coordinate System (see 70-22-201 Montana Code Annotated).

- Single Zone
- LCC Projection – 2 parallel (49 and 45 degrees)
- Employs GRS80 ellipsoid
- Contains high levels of distortion from elevated topography
- LDPC by MT DOT common practice to scale project coordinate systems

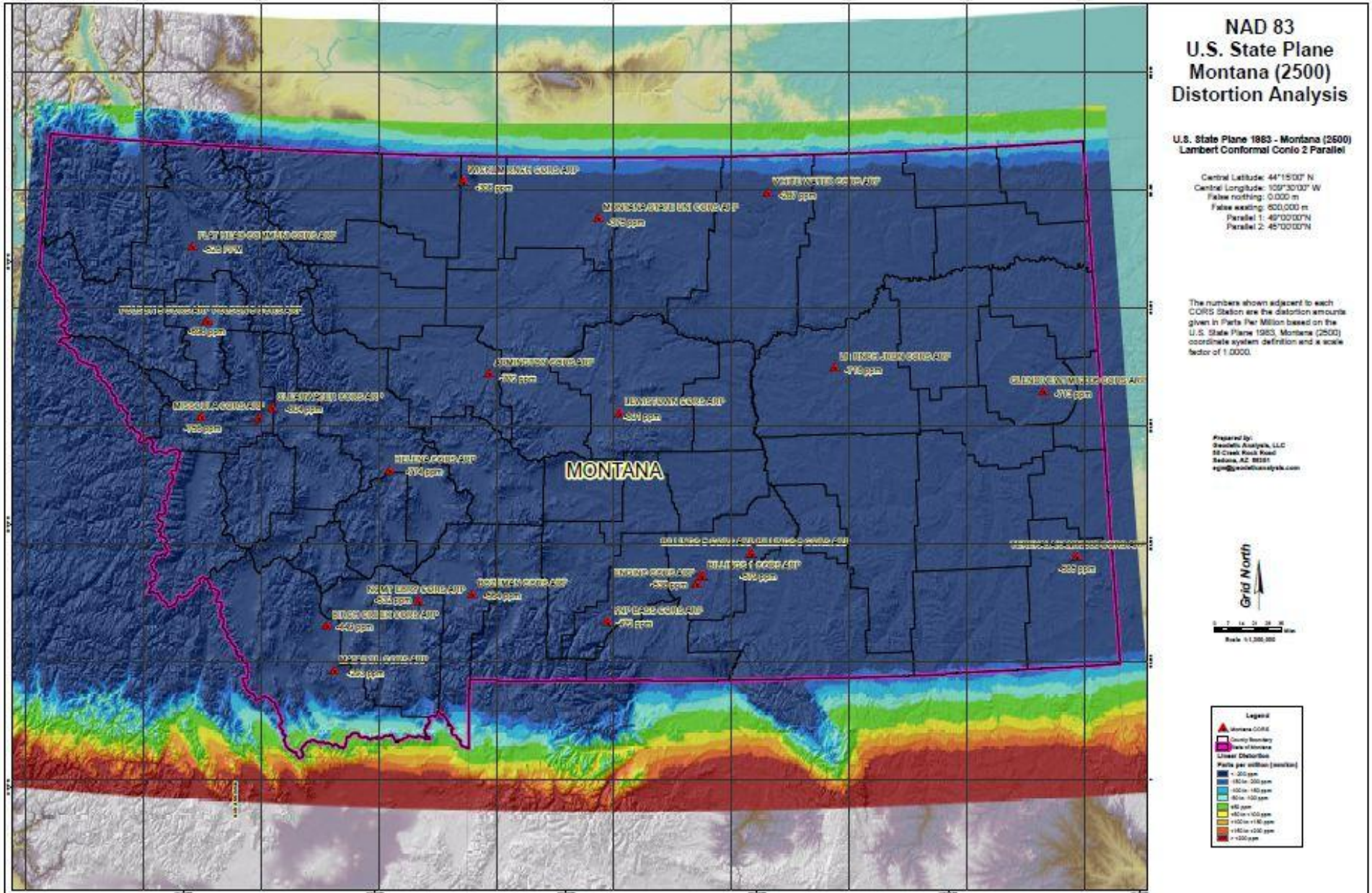
MONTANA STATE PLANE ZONE



MONTANA STATE PLANE ZONE



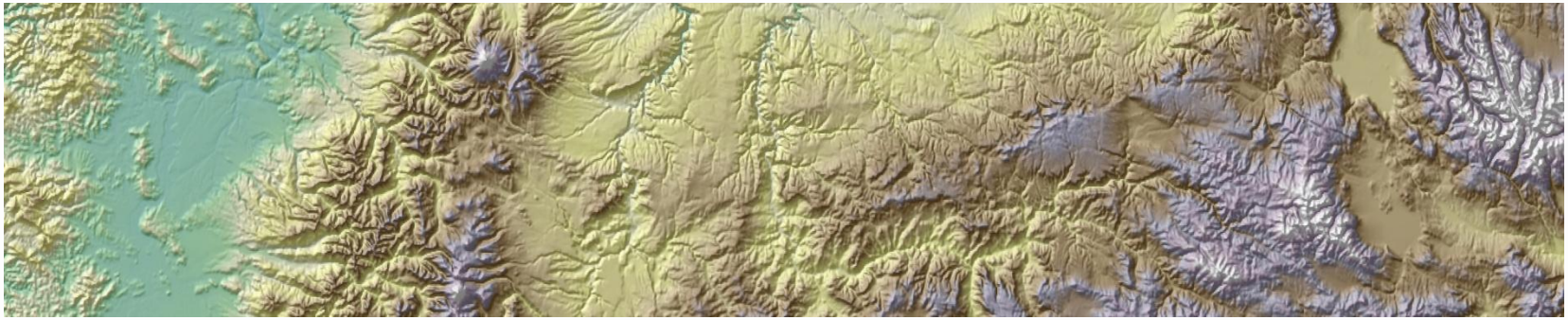
Montana State Plane Distortion Map



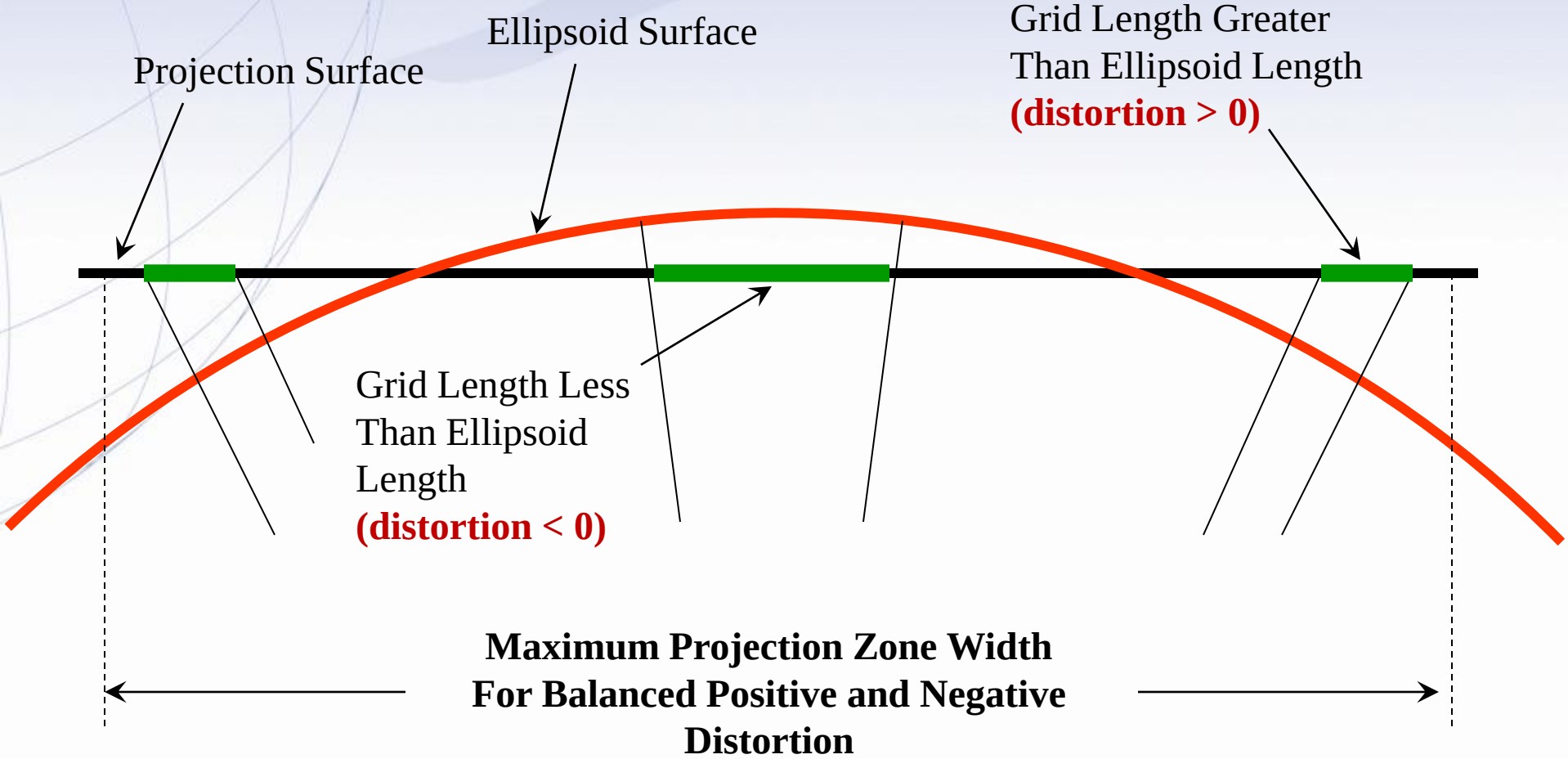
Linear Distortion Discussion

- Difference in distance between a pair of grid coordinates when compared to ground coordinates.

- Can be positive or negative
- Negative - grid length shorter than ground
- Positive - grid length longer than ground



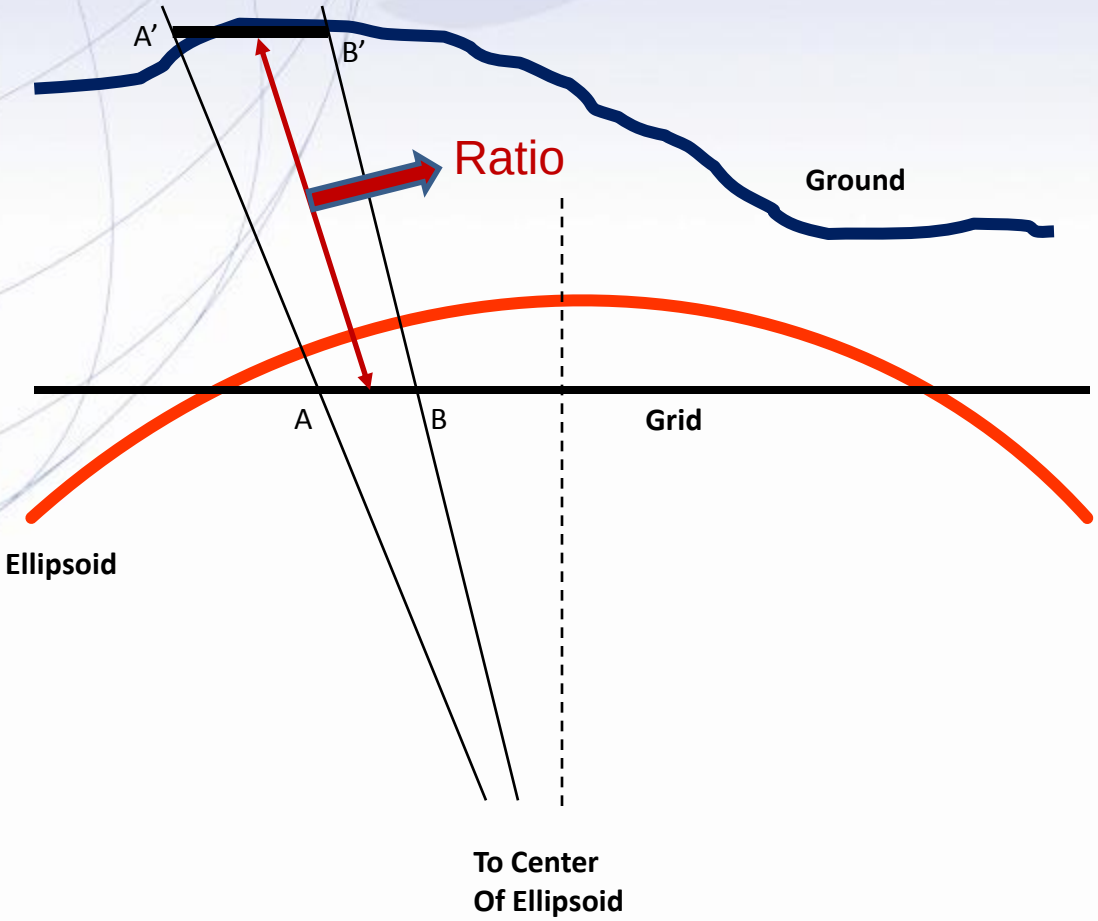
Linear Distortion



Linear 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

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 Height Above Ellipsoid

Height (ft) (above ellipsoid)	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	0.25	1:21,000
2,000	96	0.5	1:10,500
4,000	191	1	1:5,200
7,000	335	1.8	1:3,000

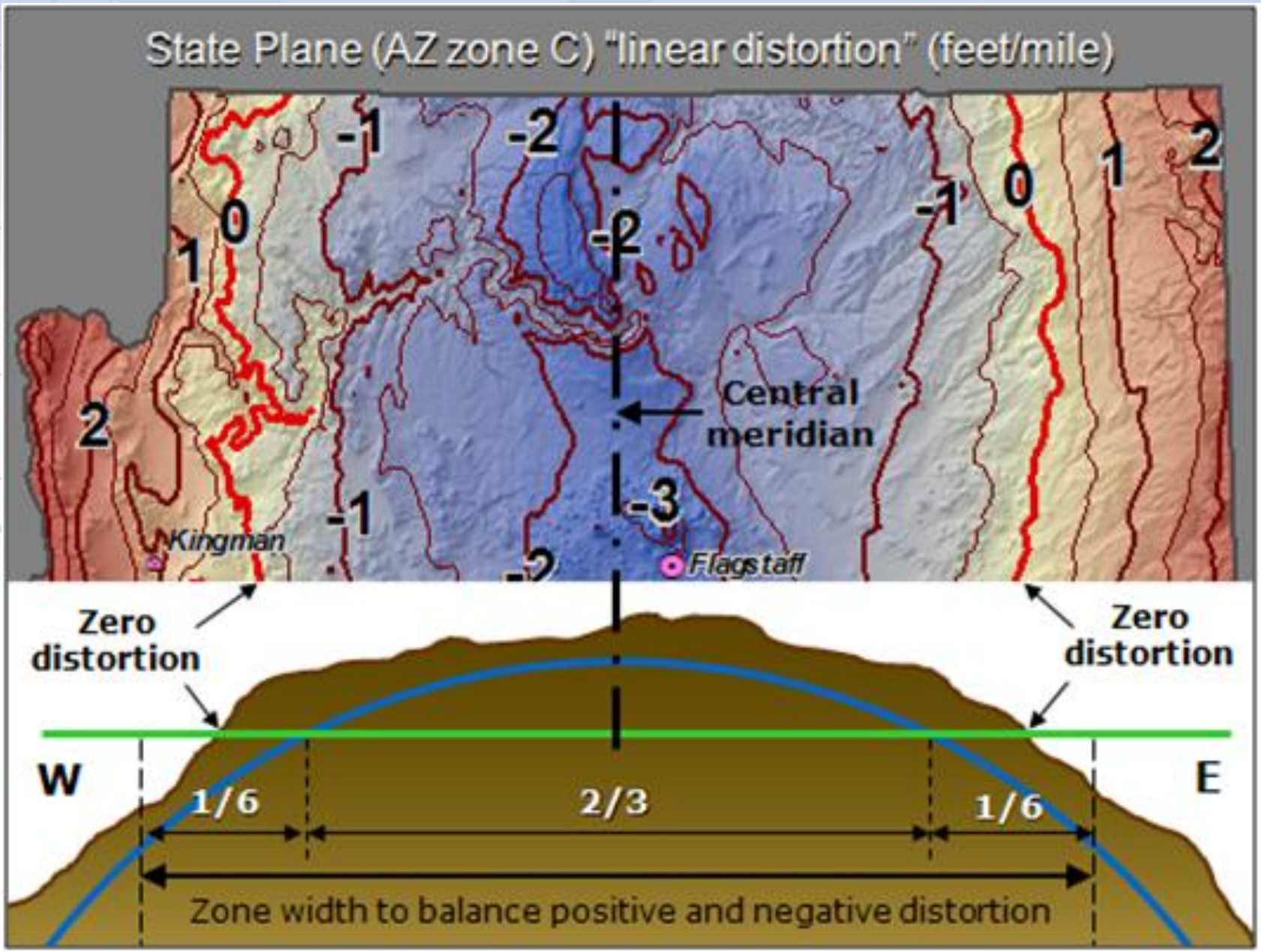
Good rule of thumb

Total Linear Distortion

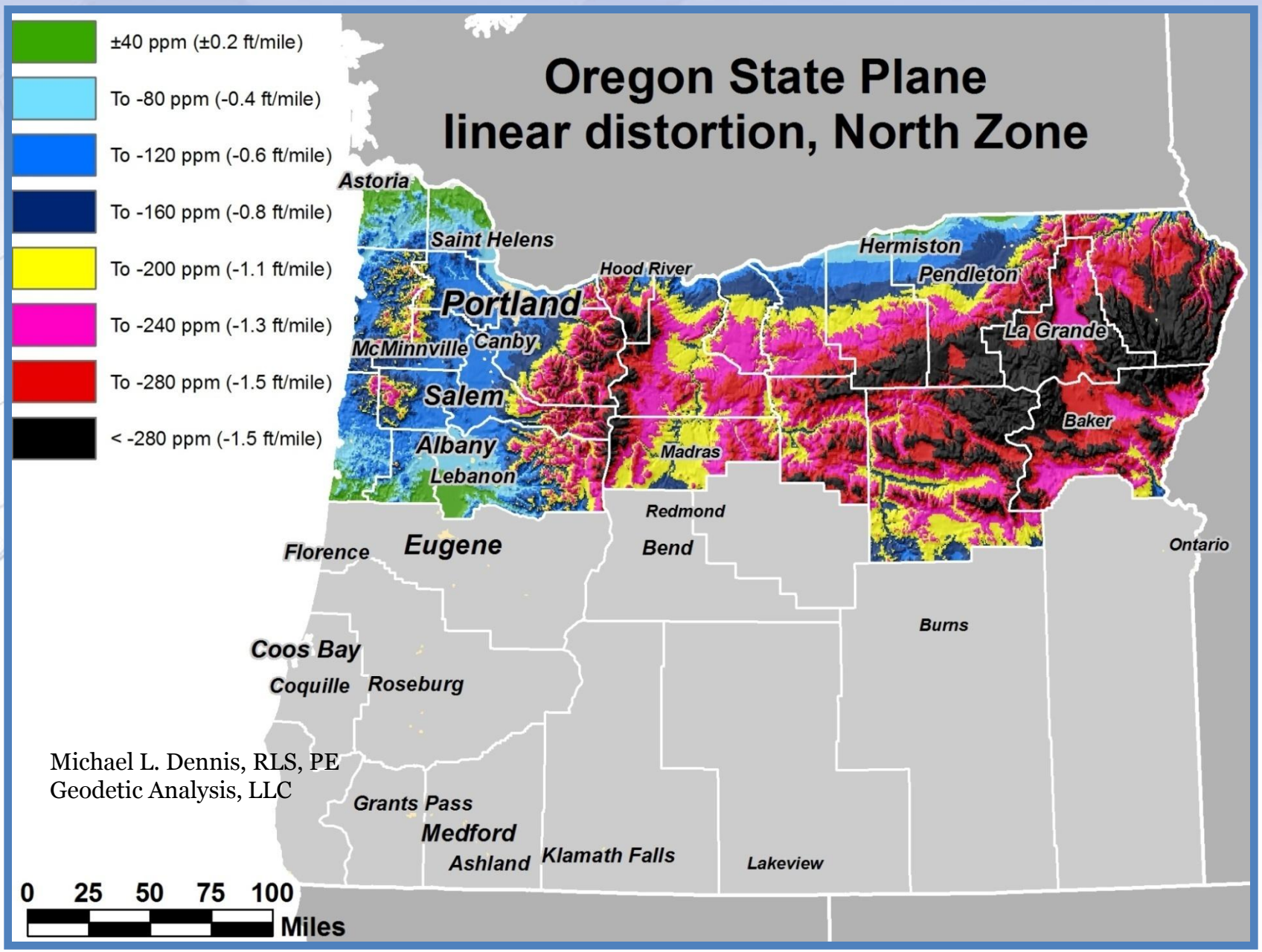
- Combination of distortion due to earth curvature and height above ellipsoid

- Often, the distortion due to the height above the ellipsoid is greater than due to curvature

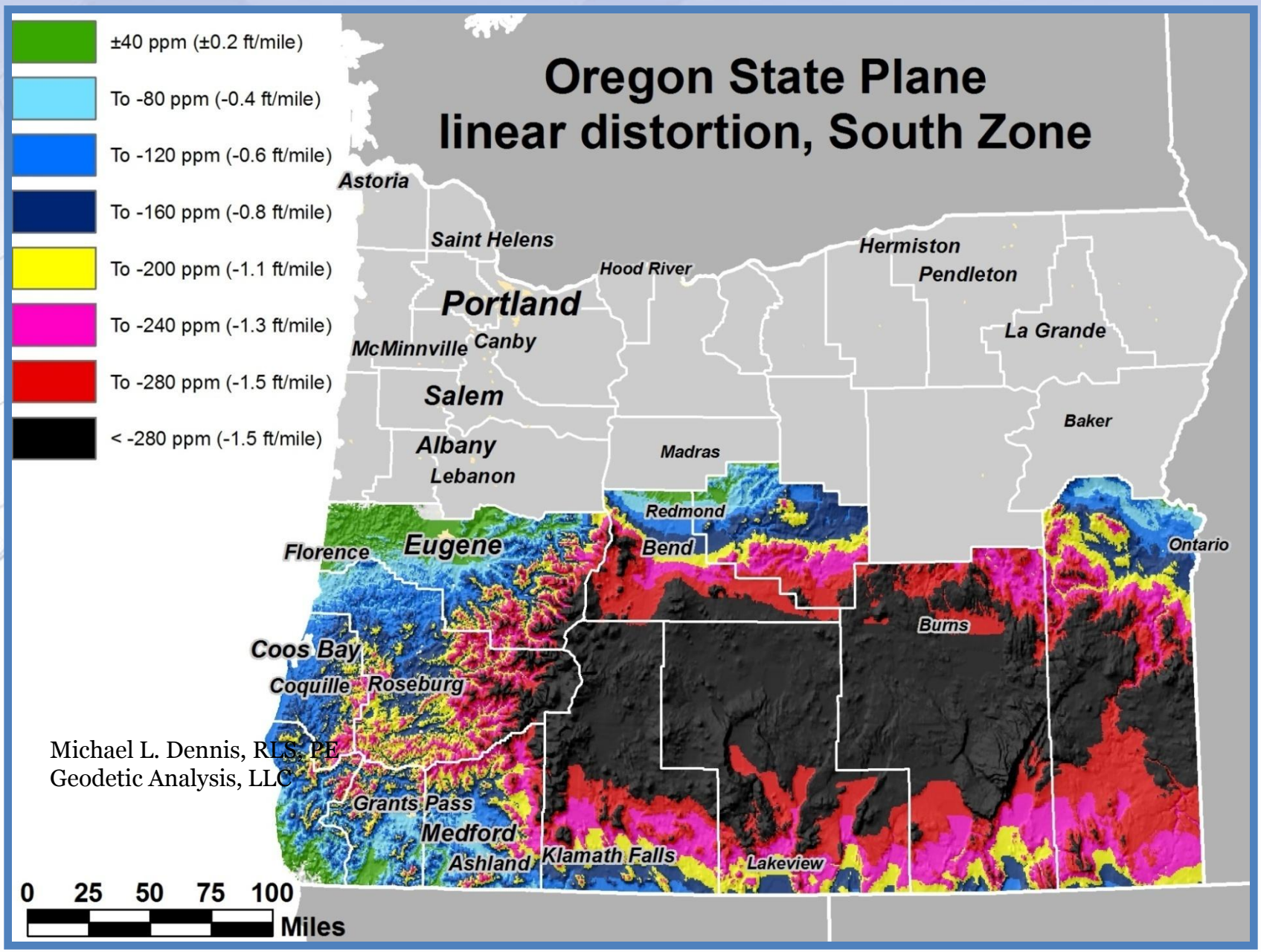
Some Examples of State Plane Distortion Maps



Montana State Plane Distortion Map



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



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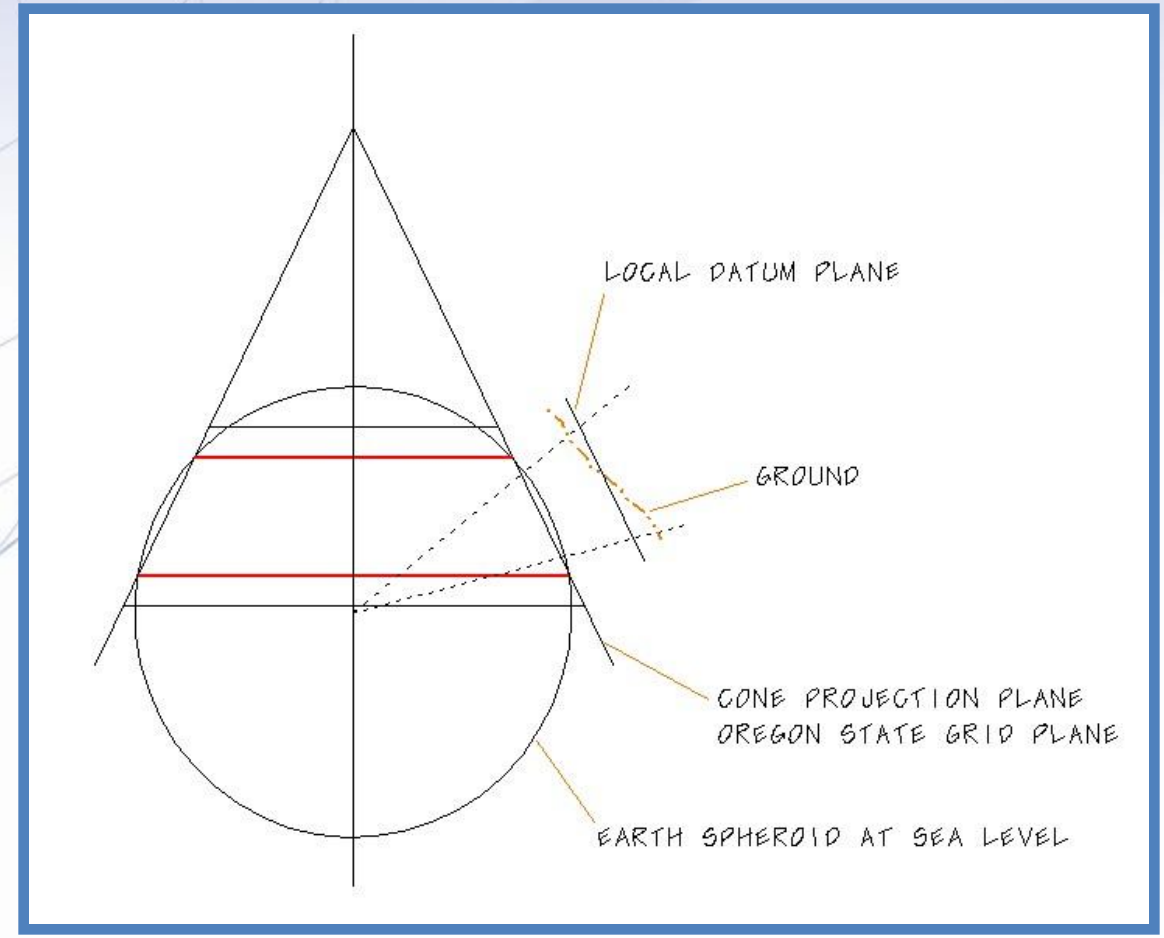
General Issues with SPC

- Does not represent ground distances well except near sea level
- Does not minimize distortion over large areas
- Does not reduce convergence angle
- Does not support modern surveying accuracy requirements
- Does not support regional GIS mapping

Scaling State Plane Up - Local Datum Plane Coordinates (LDPC)

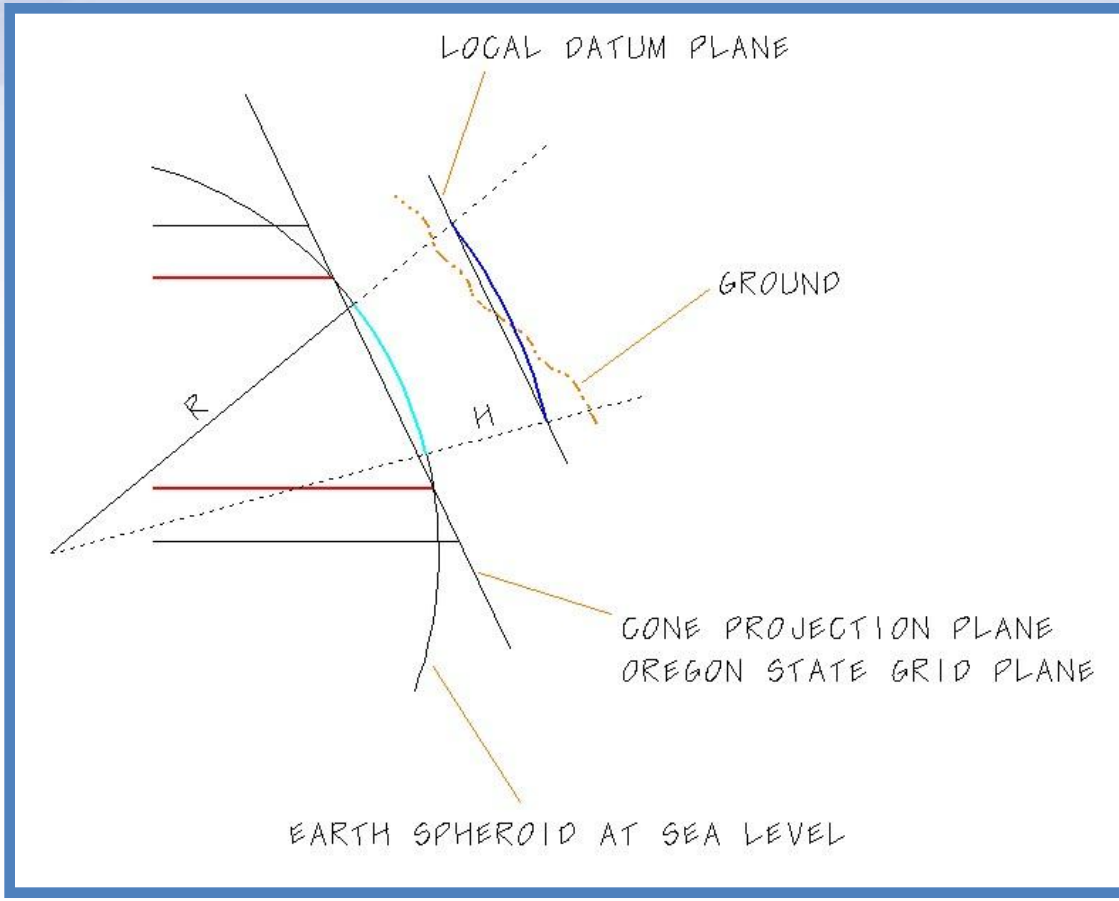


Used by many states shortly after the implementation of the State Plane System

Local Datum Plane Coordinates

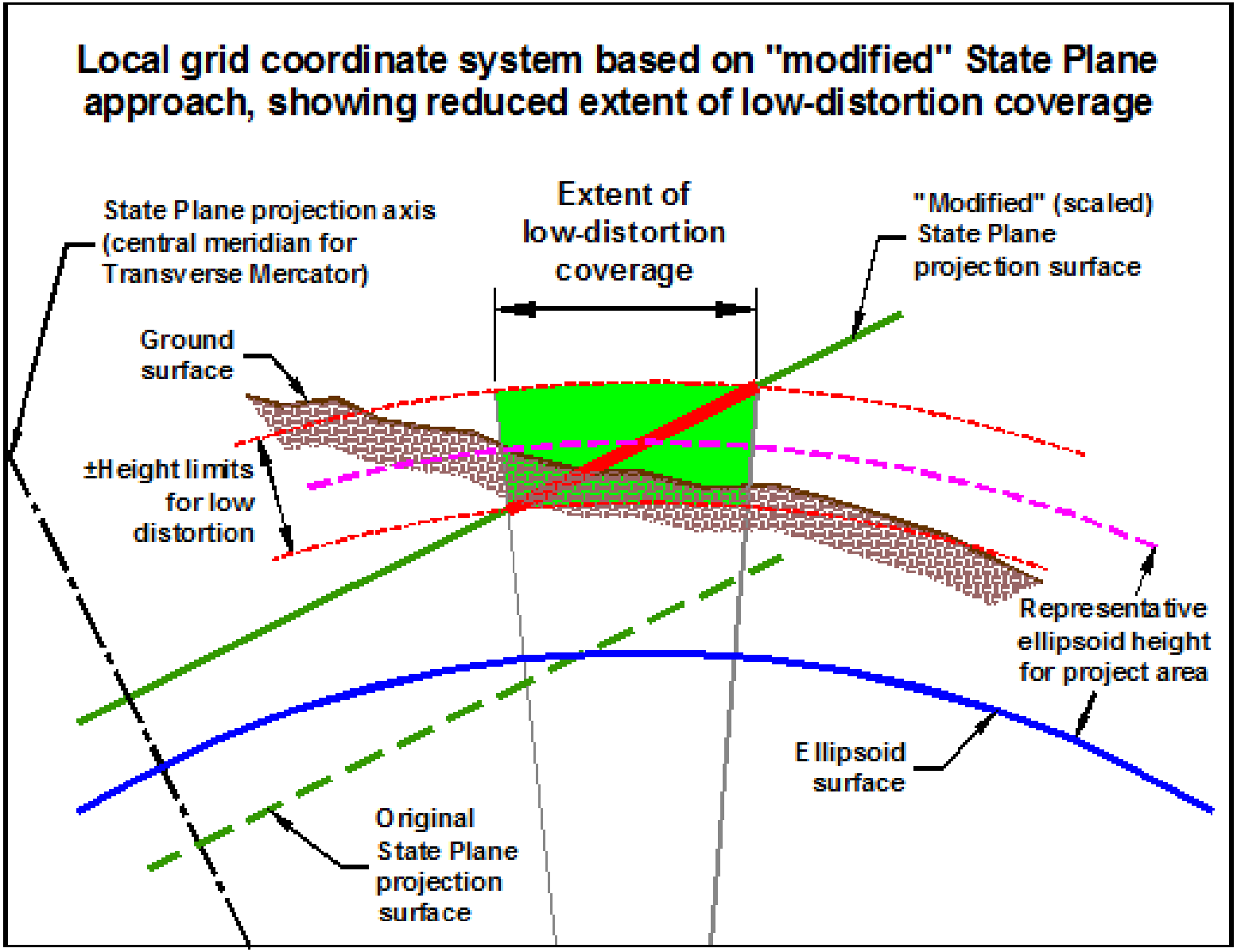
- Creates a plane close to the project elevation that is parallel to the State Plane grid

- Scaled by a <u>Combined Scale factor</u>



Some people have called this Modified State Plane

Local Datum Plane Coordinates



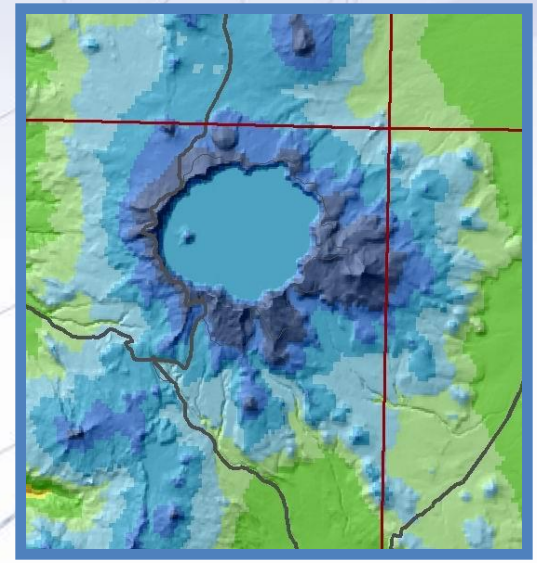
Issues with LDPC

- Small low distortion area
- LDP Coordinates look similar to State Plane but are NOT!
- Cannot be truly Geo-Referenced to NSRS
- Each project on the LDPC System is on <u>its own</u> local coordinate system, loosely tied to the State Plane system. Must be moved back to SPC before re-projecting to another zone.

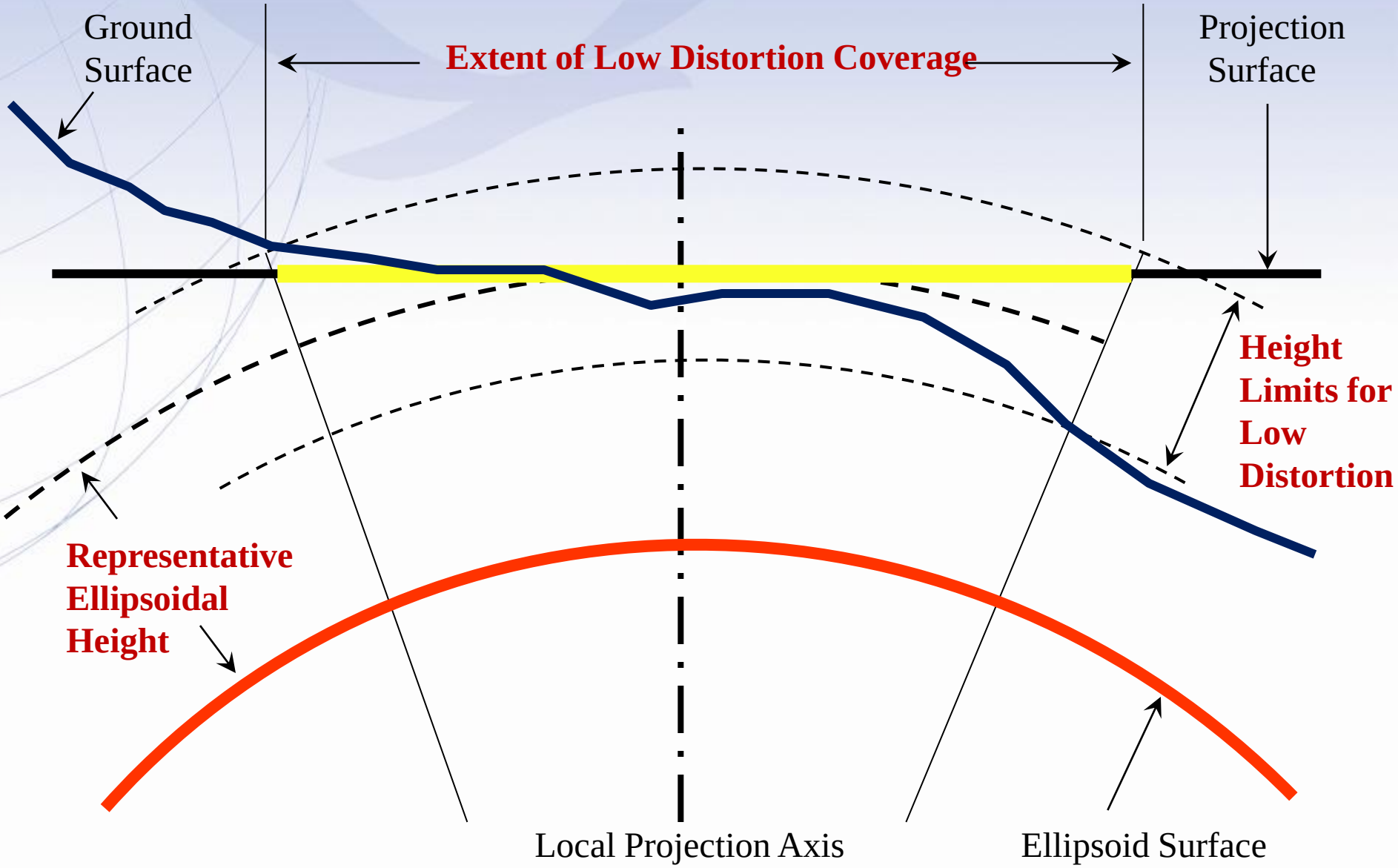
Why Change?

- Eliminate dual coordinate grids
- Requirement for higher accuracy
- Eliminate the need to convert from grid to ground
- Inclusion of geodetic surveying in our work
- Blending of GPS and TPS positioning
- Blending of Survey/Engineering and GIS Data
- Can be converted to other coordinate systems with survey and GIS software automatically OTF

Why do Low Distortion Projections Make Sense?



- Minimizes difference between Grid and Ground.
- Reduces distortion and convergence angles.
- Best possible solution for presenting surveying and mapping data available today.
- Well documented – easy to transform to between systems with existing software.
- Compatible with the NSRS (CORS).

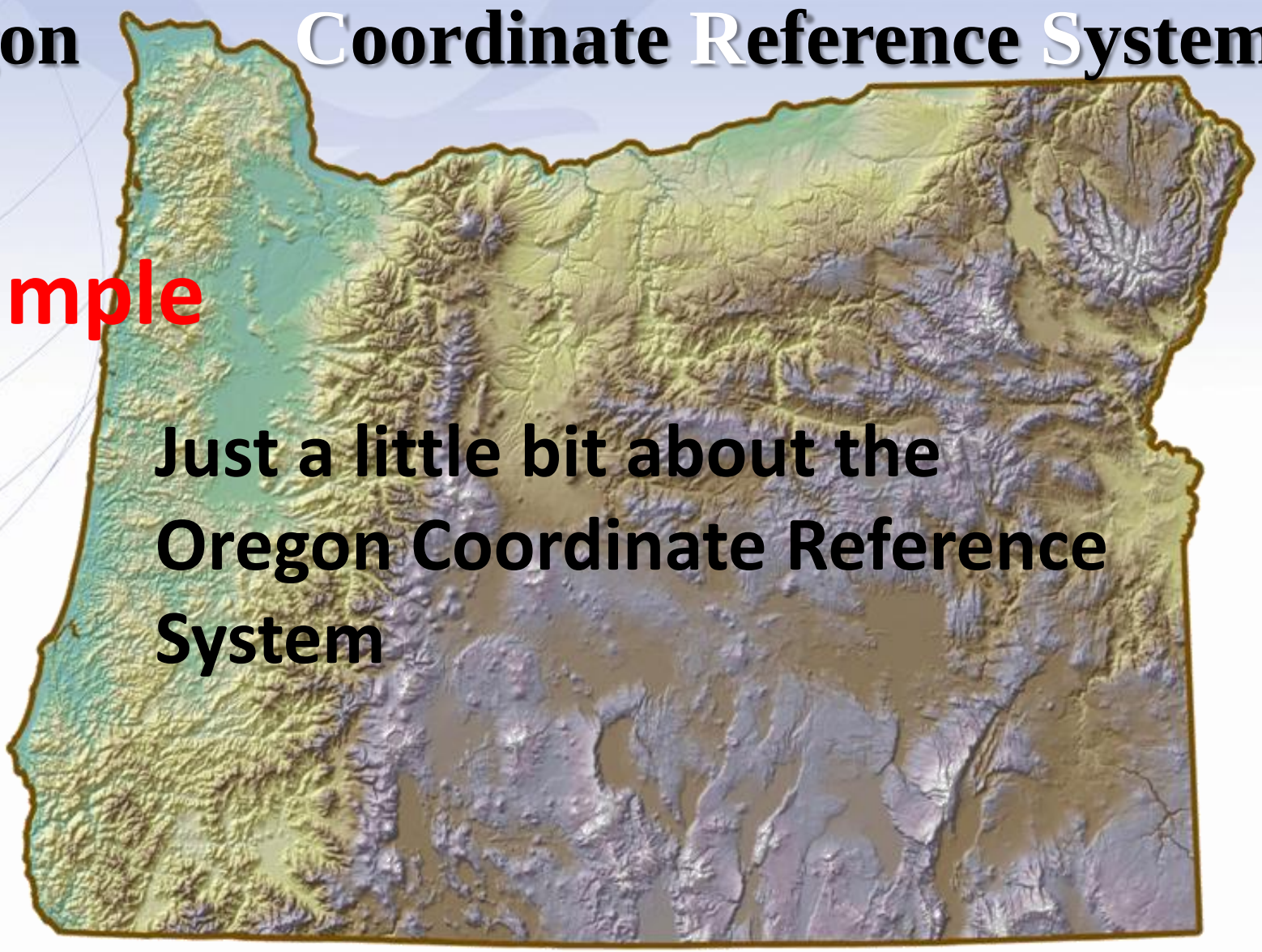

Ground Surface
Extent of Low Distortion Coverage
Projection Surface
Height Limits for Low Distortion
Representative Ellipsoidal Height
Local Projection Axis
Ellipsoid Surface

Where do Low Distortion Projections Make Sense?

- Regional mapping areas such as…
  - Counties
  - Reservations
  - Cities
  - Irrigation Districts
  - Fire Districts
  - Government Installations /bases
  - DOT Regions and Areas
  - National Parks

Or a combination of these

Oregon Coordinate Reference System

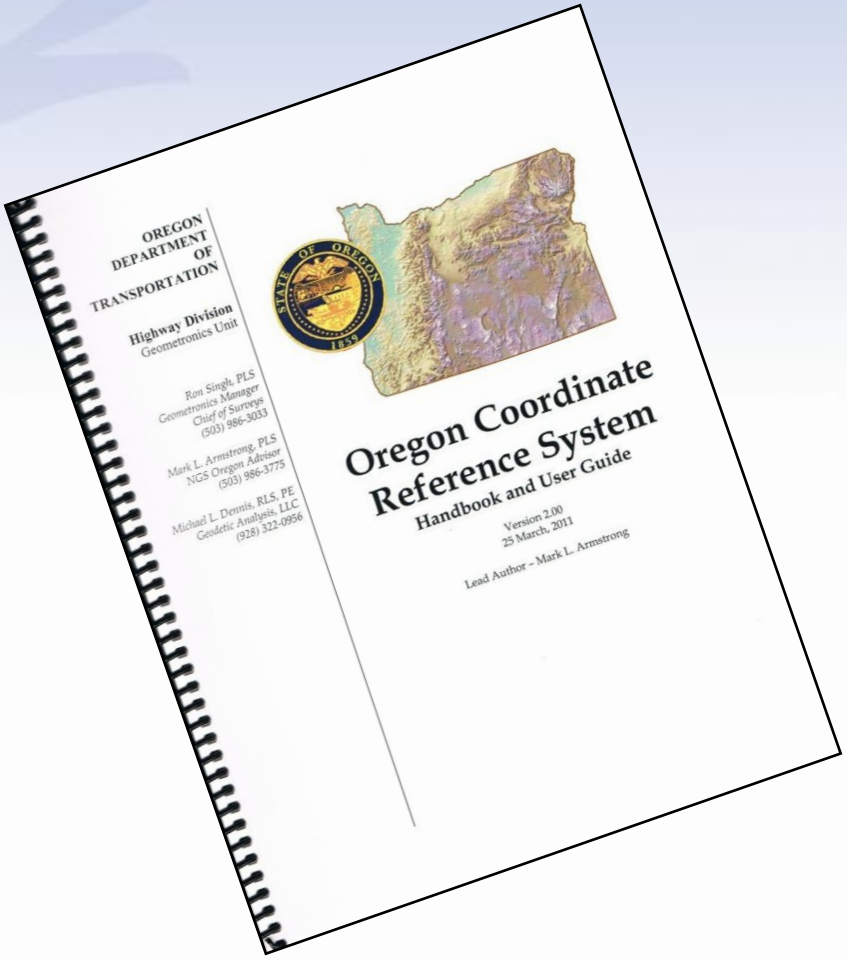


Example

Just a little bit about the Oregon Coordinate Reference System

OCRS Handbook and User Guide

Available for DOWNLOAD



http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/ocrs.shtml#OCRS_Handbook__User_Guide

History of Oregon change to add LDPs

Best Practices for Developing LDPs

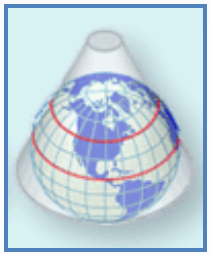
- Should be tied to the National Spatial Reference System (NSRS) with current datum frame.
- Should be a collaborative effort with Federal, State, Local, academic, and private parties. This helps assure acceptance within the government and private surveying and mapping community.
- The Real-time GPS Network (ORGN) must facilitate the use of the OCRS
- Not constrained to monuments, but provide coordinates on passive marks for checks (fiducial marks)

Best Practices cont.

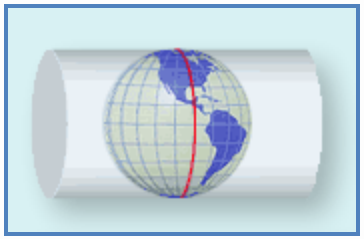
- Identify all previous LDP custom projections in use and analysis their distortion levels…and if practicable…
- Attempt to incorporate these existing projections into the statewide LDP system
- Involve PLS and GISP in the process
- Involve academic geomatics community
- Involve the local users
- Involve the software vendors

Best Practices cont.

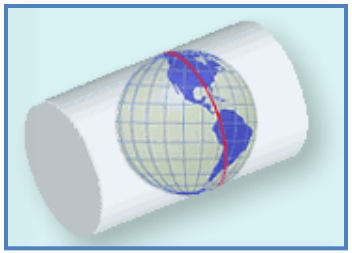
- Use a single reference ellipsoid – GRS80
- NAD83 utilizes GRS80
- Use 3 projections types:
  - **Lambert Conformal Conic**
  - **Oblique Mercator**
  - **Transverse Mercator**



East/West Zones



North/South Zones



Skewed Zones

Best Practices cont.

- Select maximum distortion values that make :
  - 1:100,000 Urban
  - 1:50,000
- Select Dis
  - Meters
  - 1 International Foot = 0.3048 meters exactly
- Metadata – document thoroughly
- Petition software vendors to include zones

Although the projection is defined in meters, the resulting coordinates are in International Feet

Example Projection Metadata

Zone Name: Local Portland
Projection: Lambert Conformal Conic
Reference Ellipsoid: GRS80

Although coordinates are based on NAD83, the "realization" utilized must be identified in your project metadata

The parameters for

1. Origin Longitude
2. Latitude of the Ce in (Φo): 45°30'00"
3. False Easting (Eo): 100 000.000 meters
4. False Northing (No): 50 000.000 meters
5. Scale Factor on Central Parallel (ko): 1.000 002 exactly

NOTE: Distance units in meters; angular units in degrees, minutes, seconds; and the scale factor is exact.

What Determines LDP Useful Physical Limits

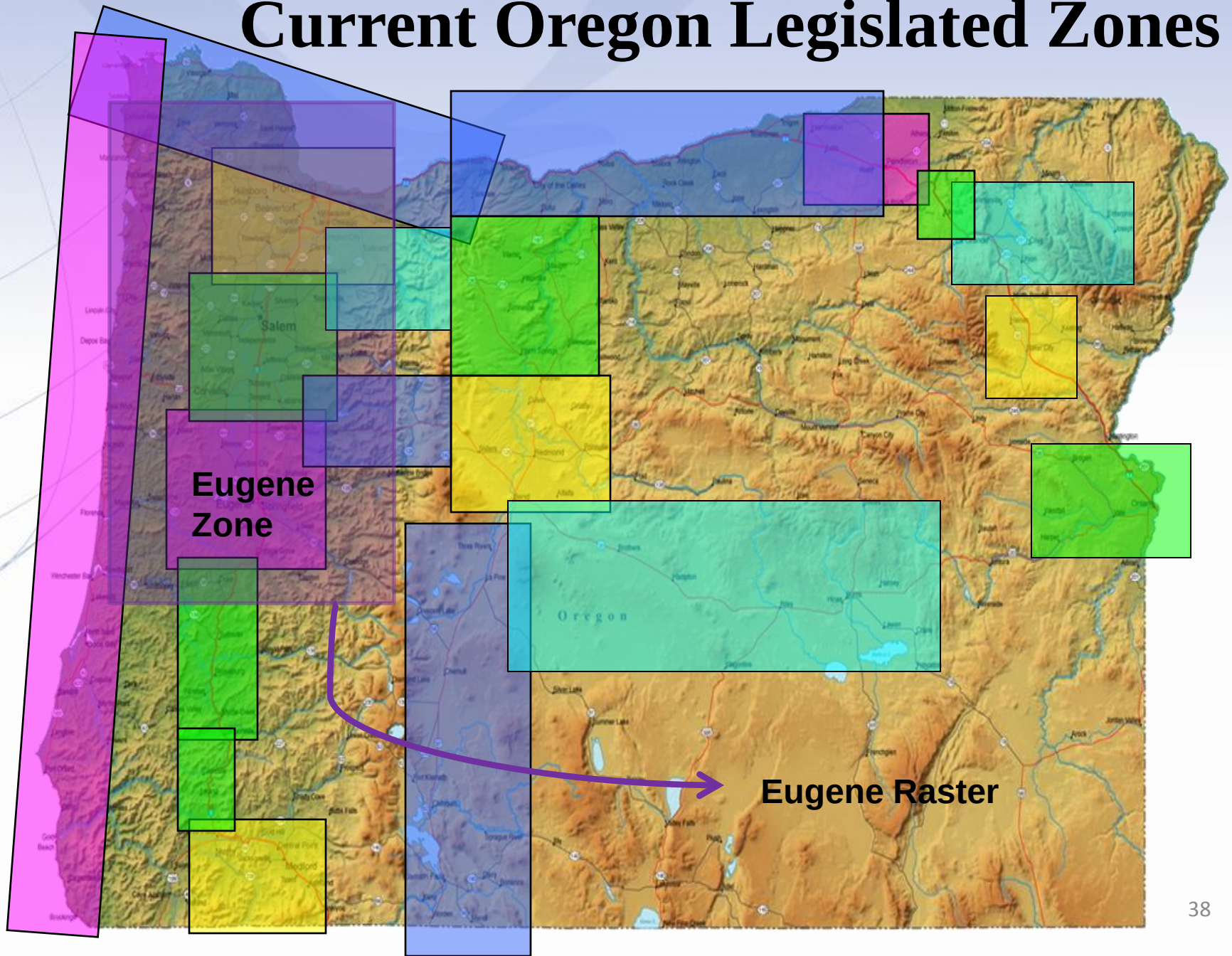
1. Topography as applied in the scale factor of the LDP design projection parameters.

2. Projection type… such as Oblique Mercador designed for one lineal feature.

3. Limits of usefulness only limited by North and East coordinates and the desire to not have negative numbers.

4. Artificial political boundaries may provide a geographical limit of intended use.

Current Oregon Legislated Zones



State Legislation of the Addition of New Coordinate Systems

10 minutes

States Survey Role

- To improve the States surveying efficiency and to enhance safety, we have been utilizing new technologies and developing new systems and procedures.

- Because these systems can benefit everyone involved in surveying, engineering, GIS, and other related fields, we have been developing these as public/private/academic partnerships and ensuring availability to all.

- Examples include the State Real-Time GPS Network and the Oregon Coordinate Reference System.

Legislative Intent

Legislative adoption will provide fundamental viable reception by engineering, surveying, and mapping professionals within the state as well as other Federal agencies such as the BIA, BLM, NGS, and FEMA. The NGS is neutral on this issue and does not endorse LDPs but understands the importance of having projects in a true coordinate system that is tied to the NSRS.

The Common Problems

- There may be no State Statute Chapter devoted specifically to geodetic survey regulations?
- There may be no State agency responsible for geodetic survey infrastructure?
- Changing survey legislation may be a major challenge through the State Surveyors Association?

The Solution – One Possible Way (Oregon)

- Develop a new ODOT OAR Division that would contain Geo-Spatial information, such as parameters for the:
  - **Oregon Coordinate Reference System**
  - **Oregon Real-Time GPS Network**
  - **Oregon State Plane System**
- The OAR to be administered by committee – ODOT, OACES, and PLSO

The Solution (continued)

- Modify ORS Chapter 93
  - To move the State Plane definitions to the OAR
  - To allow the use of the OCRS wherever State Plane is allowed
  - Update obsolete language
- Modify ORS Chapter 209
  - Update obsolete language
- Modify ORS Chapter 390
  - Beach Bill – Vegetation Line Coordinates

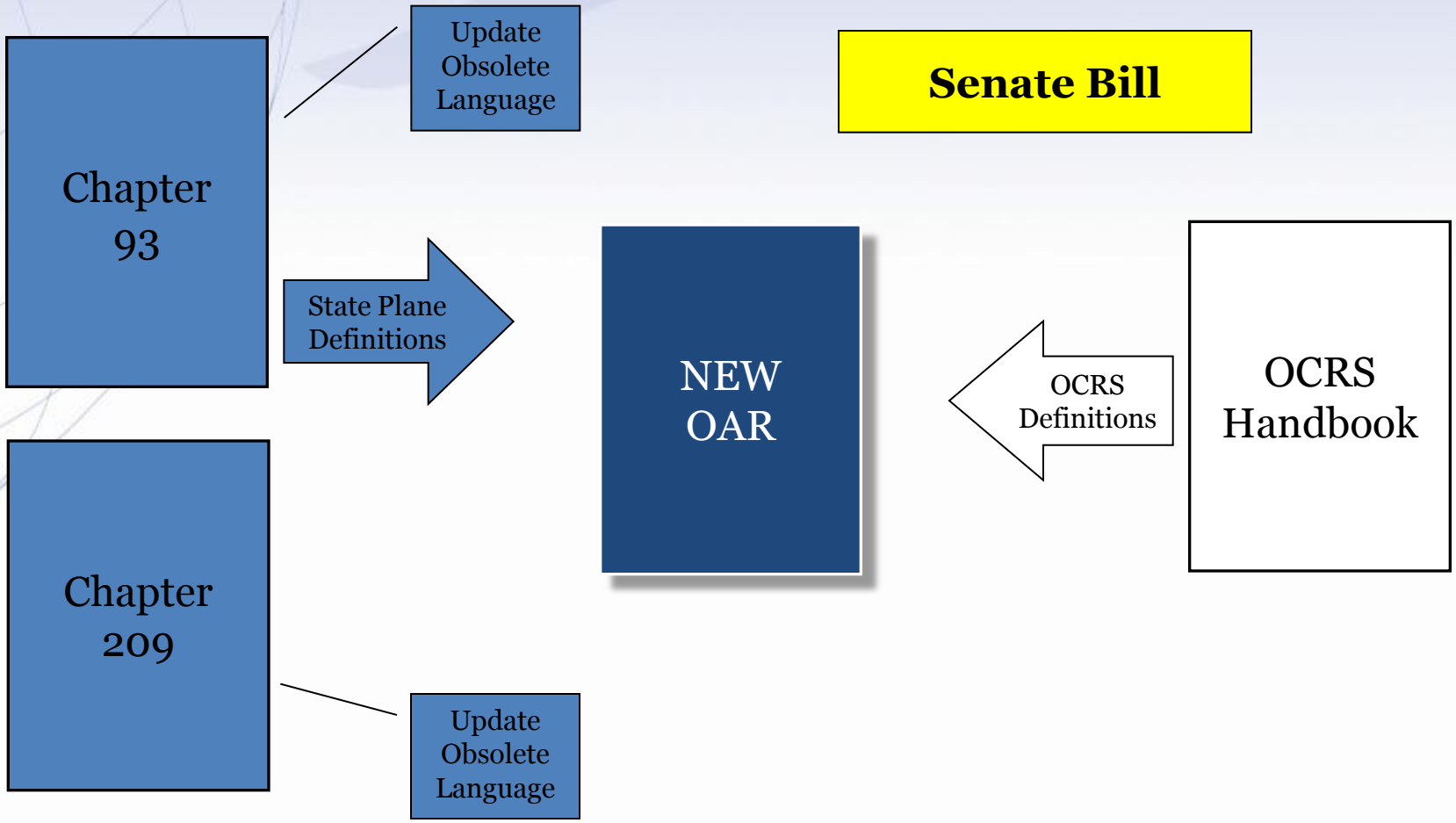
Oregon Administrative Rule (OAR)

ORS 183.310(9) defines "rule" as "any agency directive, standard, regulation or statement of general applicability that implements, interprets or prescribes law or policy, or describes the procedure or practice requirements of any agency."

Why OAR?

- More official than a manual
- The development and any amendment would require following procedures outlined in the "Oregon Attorney General's Administrative Law Manual"
  - **Advisory Committee**
  - **Public Notice – Oregon Bulletin**
  - **Notice to Legislators**
  - **Hearings**
- The history of all changes are tracked and retained permanently

Legislative Concept



Putting an LDP to Work on Your Project

- 55 minutes

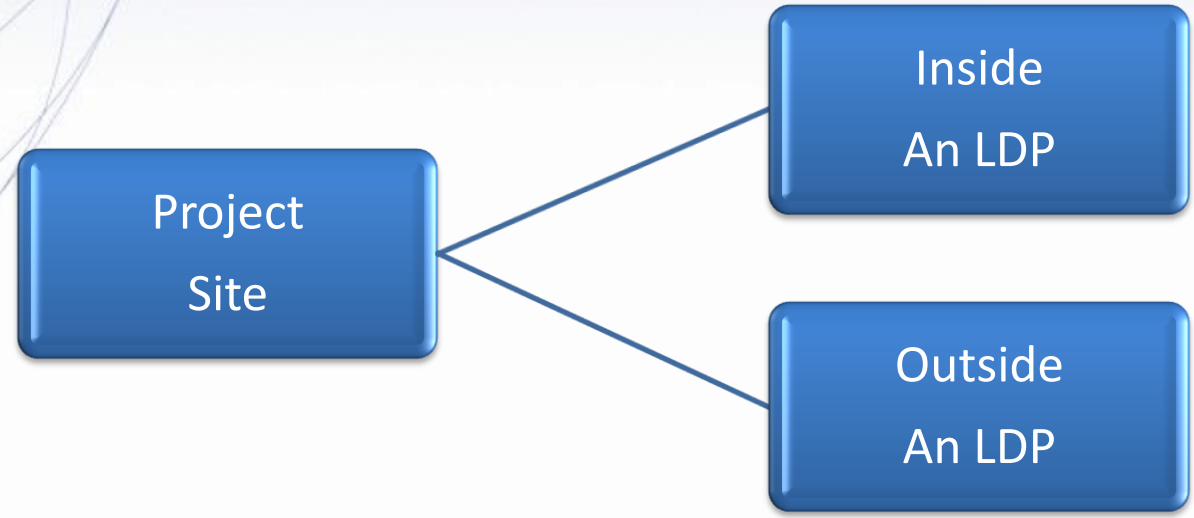
Benefits

- Single Coordinate Grid
- Grid = Ground (within some tolerance)
- Eliminate Site Calibrations
- Relate Projects Within Zone to Each Other
- Exchange Data
- Re-use Data
- Re-project Data to Other Systems
- Tied to the NSRS

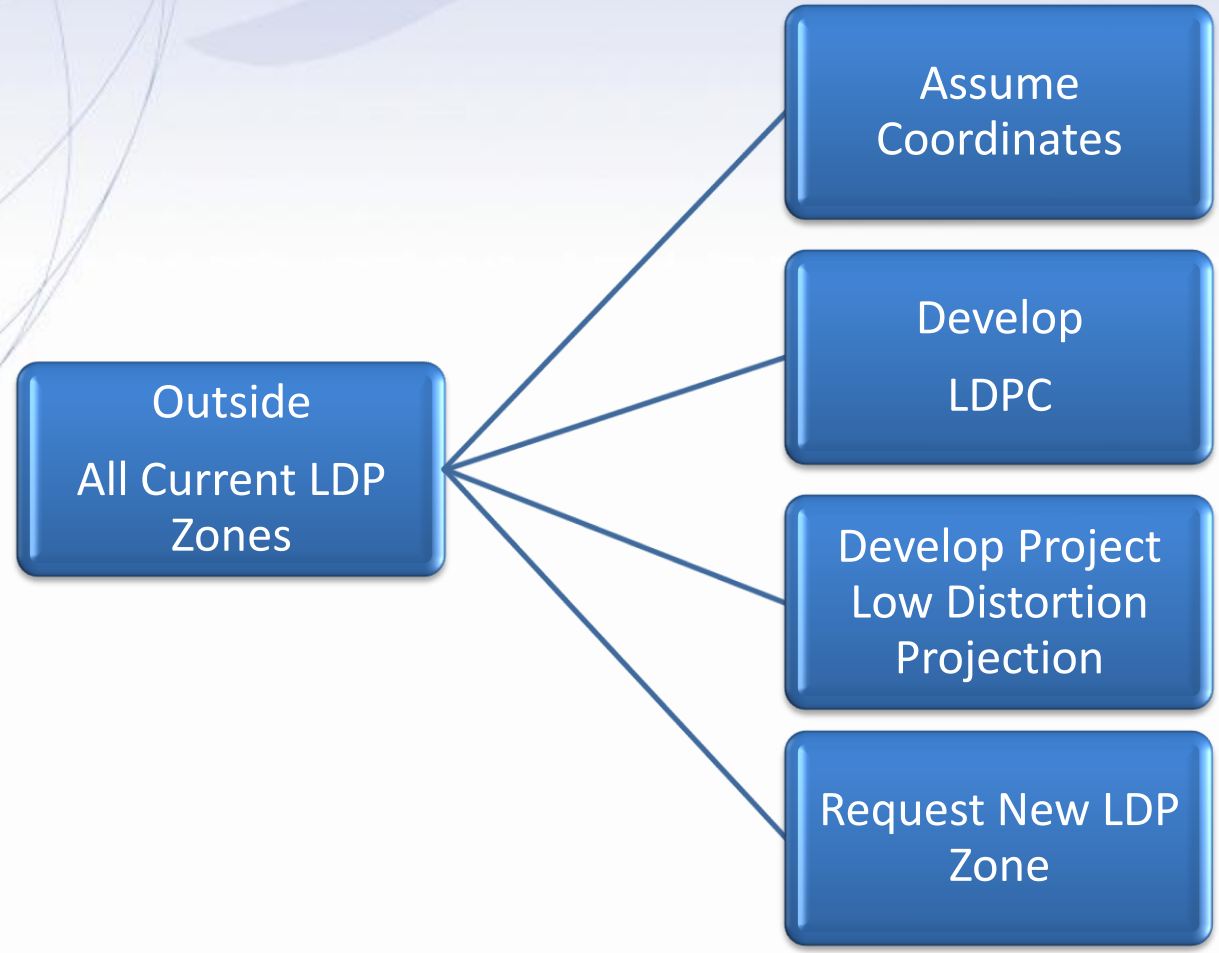
Workflow

- Determine Appropriate Zone
- Gather Information
- Configure Desktop Software
- Configure Data Collector
- Conduct Survey
- Perform Quality Checks
- Document Process

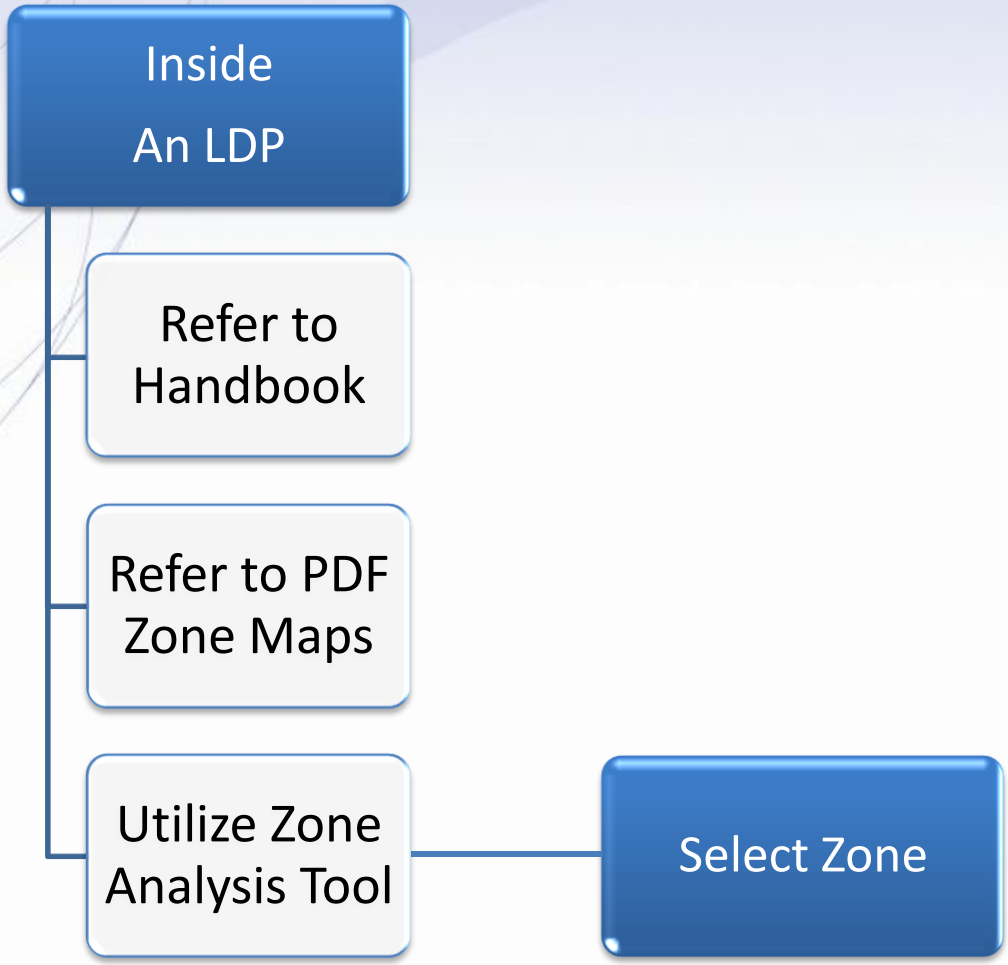
Determine The Appropriate Zone for a Project



Determine Appropriate Zone



Determining the Appropriate Zone



Zone Analysis Tool (OCRS)

- Web Based (available to everyone)
- Determine Zone at Project Site
- Determine Zone Performance at Project Site:
  - Probe
  - Polygon
  - Profile (future)
- Save Results for Project Documentation
- Beta Version

Configure Software/Data Collector

- Load the Projection Parameters
  - Manual Key-in
  - Load Pre-Configured Data Sets (manually created or from vendor software)

Use with RTN

- Typically Real-Time Networks have the ability to send the LDP Zone parameters to your GPS Controller, however, the current RTCM message type may not contain enough significant digits to load the geoid model correctly.
- **Recommend loading the projection parameters and geoid file from your desktop software. Vendors may include new zones?**

Conduct Survey

- Static GPS
  - Observe Baselines
  - Process Baselines
  - Adjust Network
  - Project to OCRS Zone
- RTK GPS
  - Load Coordinate System
  - Activate Zone
  - Collect Data
- Total Station Observations

Quality Checks

- To Validate:
  - Zone Performance
  - On the Correct Coordinate System
- Procedure:
  - Establish Geodetic Positions on Intervisible Check Points
  - Measure Terrestrial Slope Distance Between Check Points – Reduce to Horizontal Distance
  - Compare Horizontal Distance to Coordinate Inverse Values

Document Process

- Document Zone Determination
- Survey Narrative Should Identify:
  - Projection Zone
  - Horizontal Datum
  - Coordinate Realization
  - Vertical Datum
  - Geoid Model

Example of Filed Survey Metadata

Linear unit:	International foot
Geodetic datum:	North American Datum of 1983 (CORS96)Epoch2002
Vertical datum:	North American Vertical Datum of 1988
System:	Oregon Coordinate Reference System
Zone:	Salem
Projection:	Transverse Mercator
	Latitude of grid origin: 32° 20’ 00” N
	Longitude of central meridian: 109° 48’ 00” W
	Northing at grid origin: 0.000 ft
	Easting at central meridian: 200,000.000 ft
	Scale factor on central meridian: 1.00014 (exact)

SAMPLE

All distances and bearings shown hereon are grid values based on the preceding projection definition.

The basis of bearings is geodetic north. Note that the grid bearings shown hereon (or implied by grid coordinates) do not equal geodetic bearings due to meridian convergence.

Reference Material

The Best Place to Start is the OCRS Web Site:

www.oregon.gov/ODOT/HWY/GEOMETRONICS/ocrs.shtml

Here, you will find:

- The OCRS Handbook and User Guide
- OCRS Zone Maps
- OCRS Zone Analysis Tool
- Presentation and Training Material
- Data Collector Configuration Files
- Links to Other Information

The Surveyor's Emerging Role

- 5 minutes

Old Paradigm

- All About Individual Project Final Products
- Monuments on the Ground
- Static Maps and Plats
- Rubber Sheeting or Loose Conversion to Fit Other Projects

New Paradigm

- Old Paradigm, PLUS…

- Significant Value Given to Data!
  - Accuracy Defined
  - Quality Assurance
  - Fitness for Use
  - Epoch (time stamp)
  - Reference Frame (NSRS)
  - Value Added Coordinate System
- Used by Geospatial Data Experts
- Used by Data Managers
- Academic Science Approach Applied

Questions?