Designing and Testing Low Distortion Projections

Montana Association of Registered Land Surveyors 2012 Conference

35 Slides

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With additional Slides from Michael Dennis and Geodetic Analysis

Designing and Testing LDP Projections

- **Step 1:** Determine Best Practice Approach

  How will you proceed??

  – Recommend gathering 5 to 10 people enlisted as Technical Team

  – Develop list of important goals as part of the 'Best Practices'

  – Consensus of opinion important to acceptance by the masses

  – Each all day meeting can develop 1-4 LDPs

Use Conformal Projections

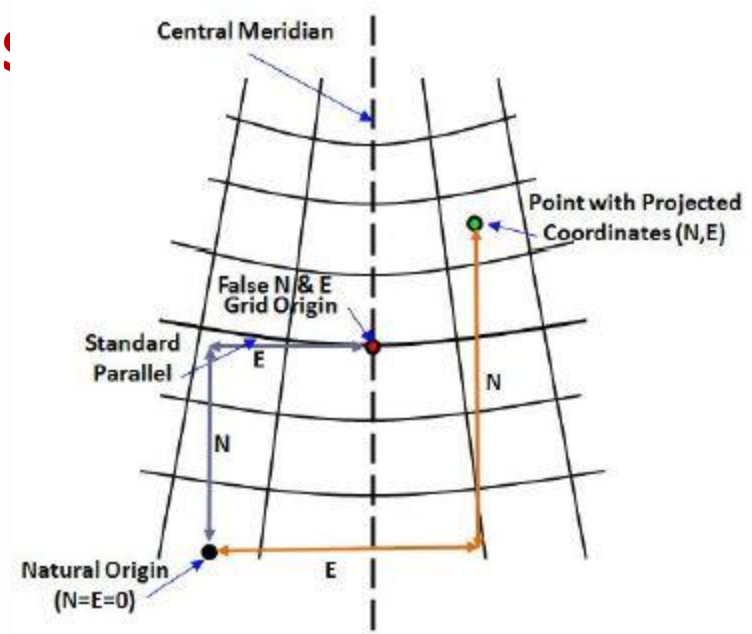
- Conformal map projections are the class of projections in which angles on the surface to be mapped are preserved, that is, corresponding angles on the map plane and the surface are equal.
- Conformal map projections allow geodetic calculation common in surveying and engineering practice.

Use Conformal Projections

- **Step 2:** Pick a projection model
  - **Lambert Conformal Conic (LCC) single parallel**
    - Best used to cover areas long in the E-W direction
  - **Transverse Mercator**
    - Best used to cover areas long in the N-S direction
  - **Oblique Mercator (OM)** – Rectified Skew Orthomorphic (RSO) Type
    - Best used to cover long lineal features at an angle or skew

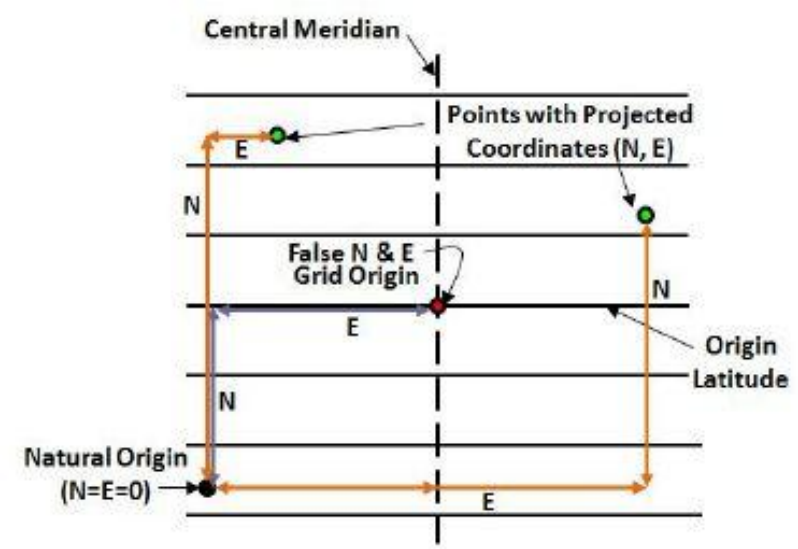
Lambert Conformal Conic (LCC) Single Parallel

- Superimposes cone over ellipsoid
- Has only <u>one reference parallel tangent to or scaled above the ellipsoid</u>
- Can cover relatively large regions of a State
- **Use where topo height changes uniformly in the N-S direction**



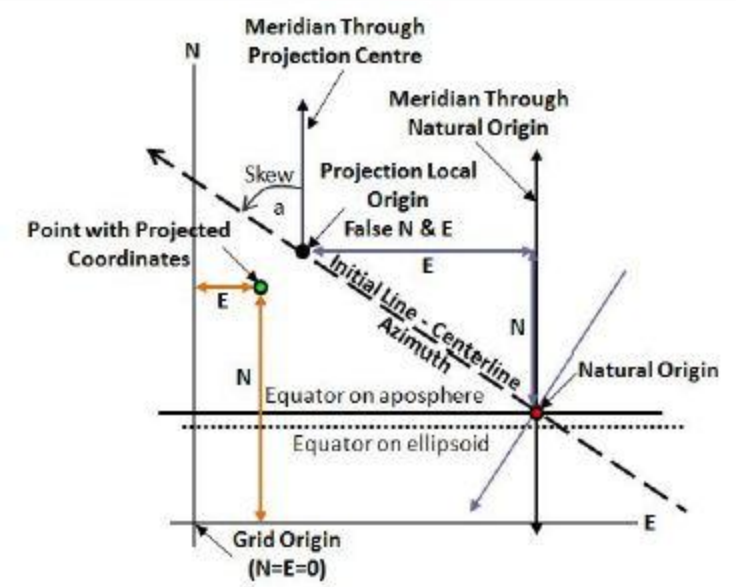
Transverse Mercator

- Superimposes cylinder over ellipsoid
- Has a Central Meridian <u>tangent to or scaled above the ellipsoid</u>
- Can cover relatively large regions of a State
- **Use where topo height changes more or less uniformly in the E-W direction**

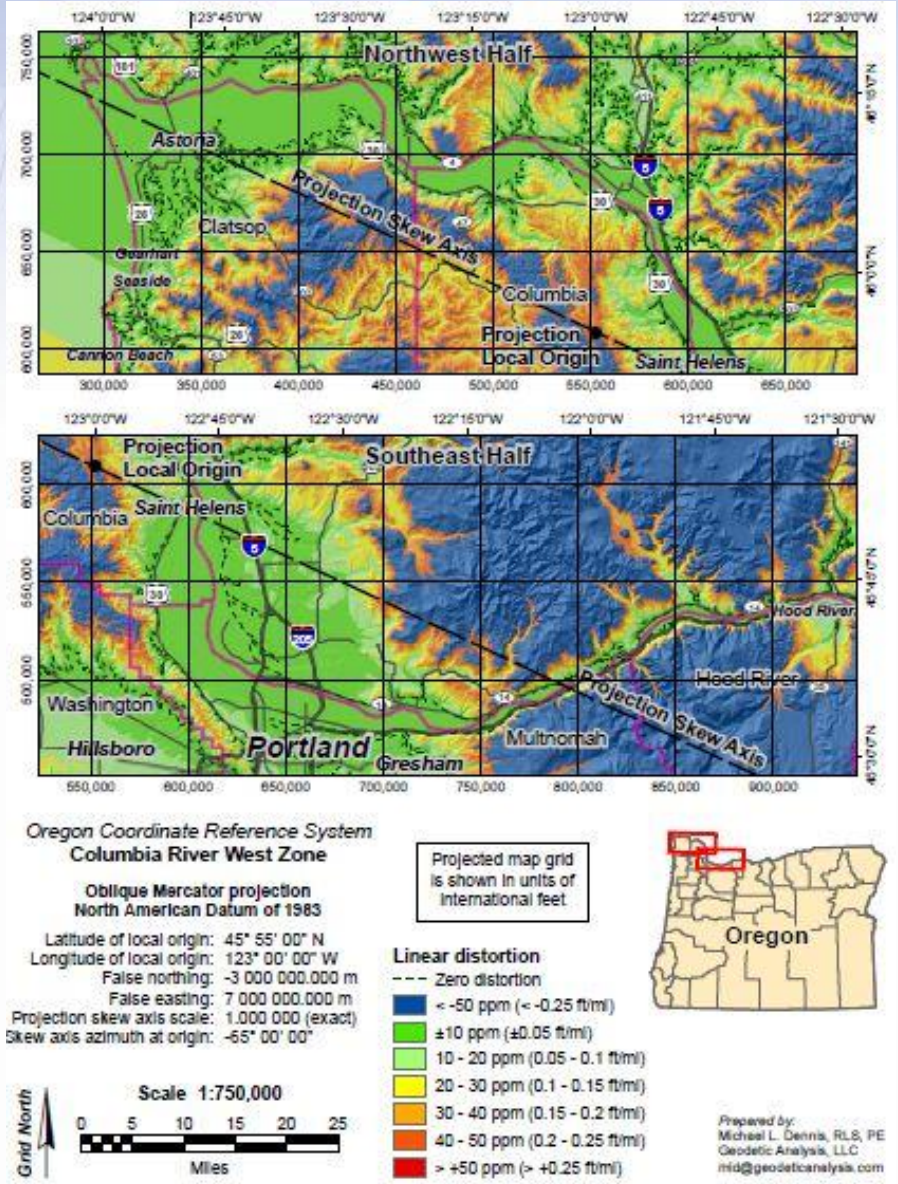


Oblique Mercator (RSO)

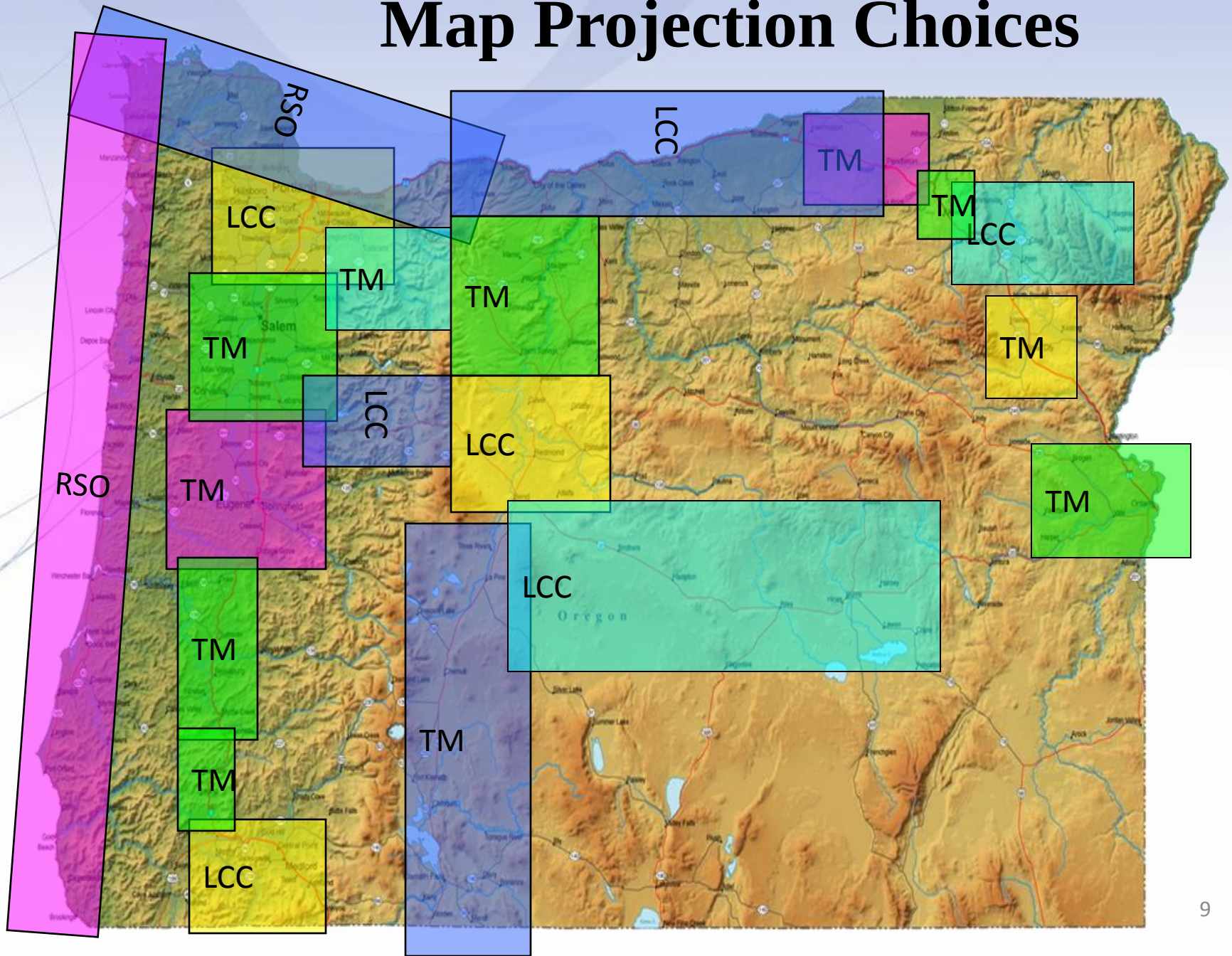
- An oblique form (rotated cylinder) of the Mercator conformal projection.
- Has one center line rotated and aligned to fit a lineal feature such as a highway or pipeline or power line corridor that is <u>tangent to or scaled above the ellipsoid</u>
- **Can cover long narrow areas**



Oblique Mercator (RSO) Example



Map Projection Choices



Facts To Remember

- All map projections produce distortion so the goal is to minimize that distortion
- Each distorts in a unique way since the ground it covers is uniquely different
- Picking the right type of projection my not be obvious and will require trials!!
- Distortion can be positive AND negative
- **LDPs best defined in terms of topography and not political boundaries although both may be used as a defining set.**

Tools You Will Need

- Good digital topographic map… (The national seamless DEM from USGS)
- Coordinate manager software – Survey or GIS
- Use of knowledgeable consultant to streamline the process and provide a neutral viewpoint?
- Survey equipment – total station and GPS to test… grid vs ground distances

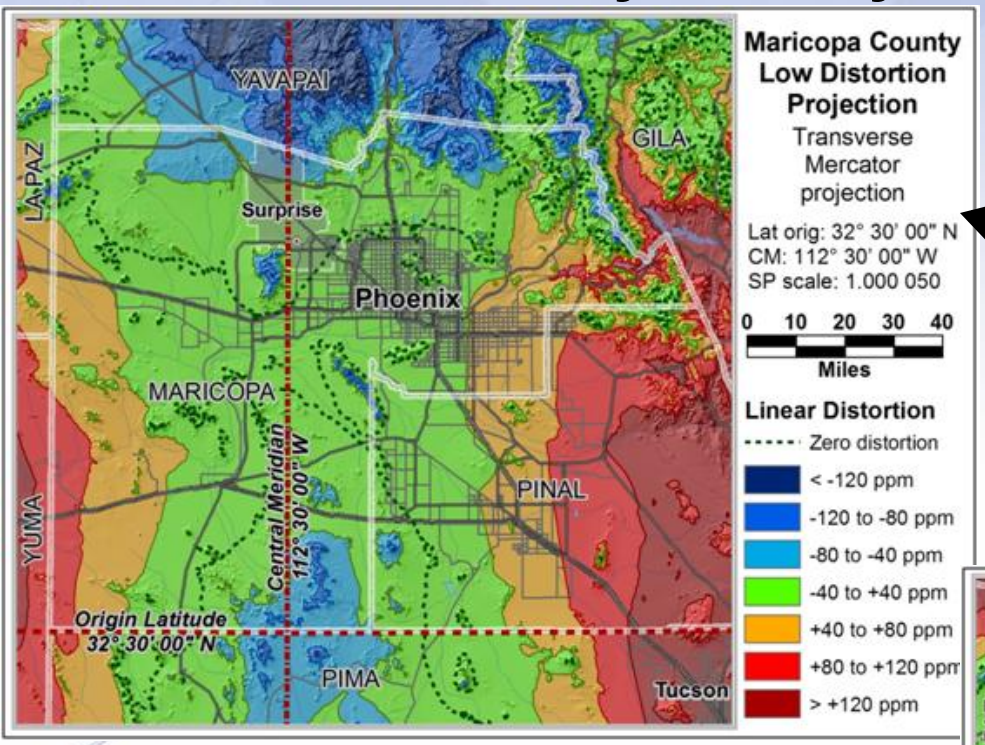
Build The Projection

- **Step 3:** Define the project area
  - Choose a representative ellipsoid height (not elev.)
    - Nearest 10-20 feet good enough
  - Choose the projection type (try both TM and LCC)
    - Place the projection axis near the center of the project area
  - Scale the central meridian or parallel to the representative ground height
  - Check the distortion at points distributed throughout the project area then refine the scale and CM/parallel location.

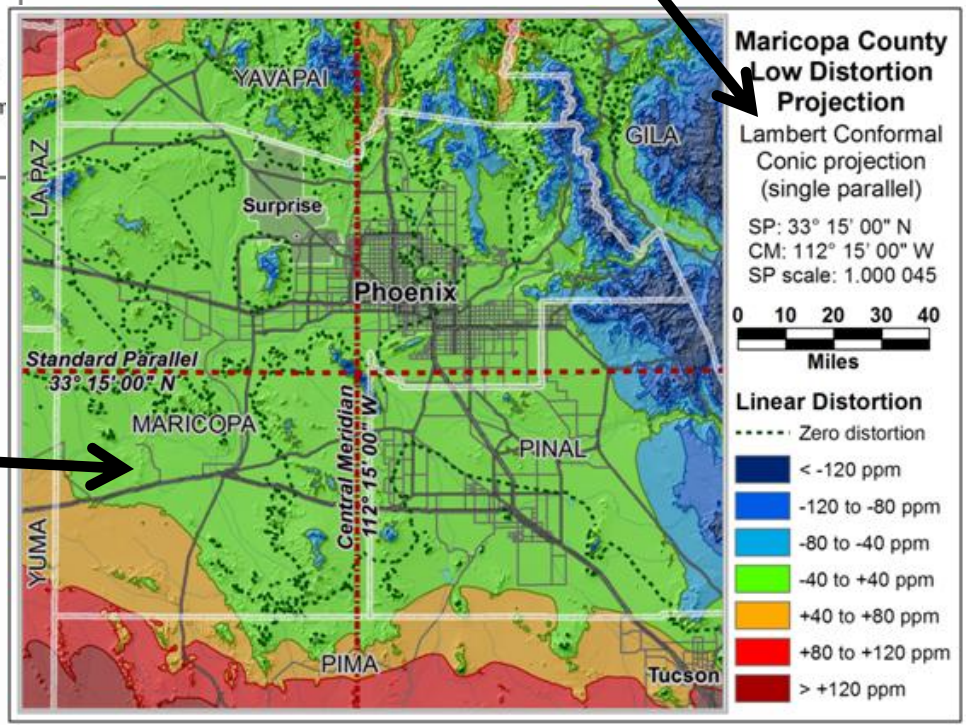
Build The Projection, cont.

- Keep the projection definition clean and simple!
  - Define the scale (*k*) to six decimal places (e.g. 1.000230)
  - Define the grid origin using whole values (false N&E)
- What ppm of distortion can you live with?
  - +/-10ppm or +/-20ppm or ???
- Define the linear UNIT and GEOMETRIC REF. SYSTEM
  - Parameters can be metric and projects can be english
  - The datum tag is <u>not</u> part of the LDP zone parameters but essential as meta-data when applied to a project
  - The datum tag should normally represent the current NSRS reference frame

Trial and Adjust - Projection Type, Axis, and Scale



Test distortion area changes by changing projection types and moving the CM/SP and changing the scale



Note the increase in green (40ppm range)

Zone Parameters

- Name the Zone
- Projection Type: **TM**
  - Latitude of Grid Origin
  - Central Meridian
  - False Northing
  - False Easting
  - Scale (exact)

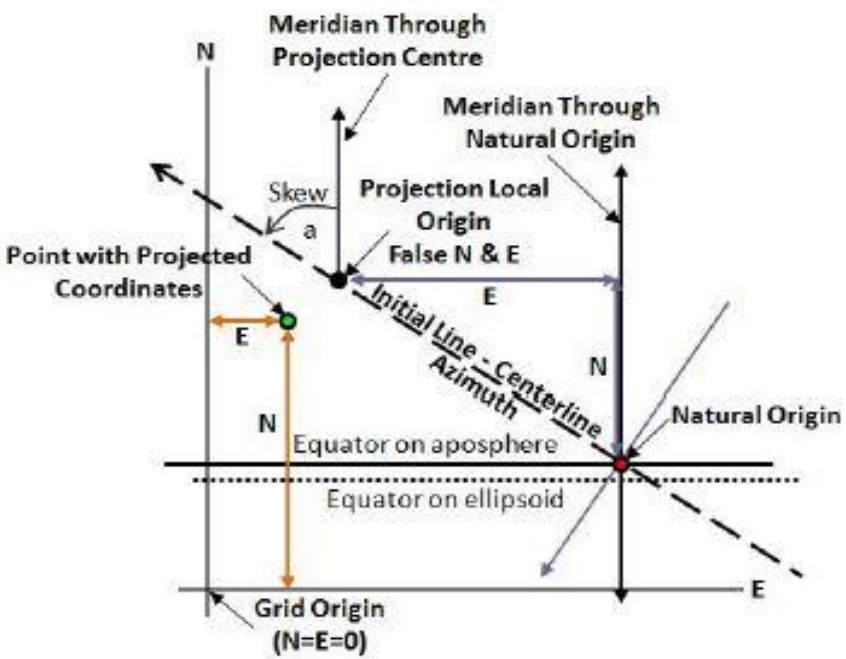
Zone Parameters

- Name the Zone
- Projection Type: **LCC**
  - Standard parallel and grid origin
  - Central Meridian
  - False Northing
  - False Easting
  - Scale (exact)

Zone Parameters

- Name the Zone
- Projection Type: **OM (RSO)**
  - Latitude of grid origin
  - Angle skew or azimuth
  - Longitude of local origin
  - False Northing
  - False Easting
  - Scale

The specified 'grid origin' is located where north and east axes are zero. In contrast, the 'natural origin' of the projected coordinates is located where the 'Initial Line' of the projection crosses the 'equator of the aposphere' (a surface of constant total curvature), which is near (but not coincident with) the ellipsoid at the equator.



Required Meta-data

- **For a complete coordinate system…**
- Ellipsoid – GRS80
- Horiz. Datum and RF: NAD 83(2011) epoch 2010.00
- Vert. Datum: NAVD 88
- GEOID Model: GEOID12

Field Testing and Proofing

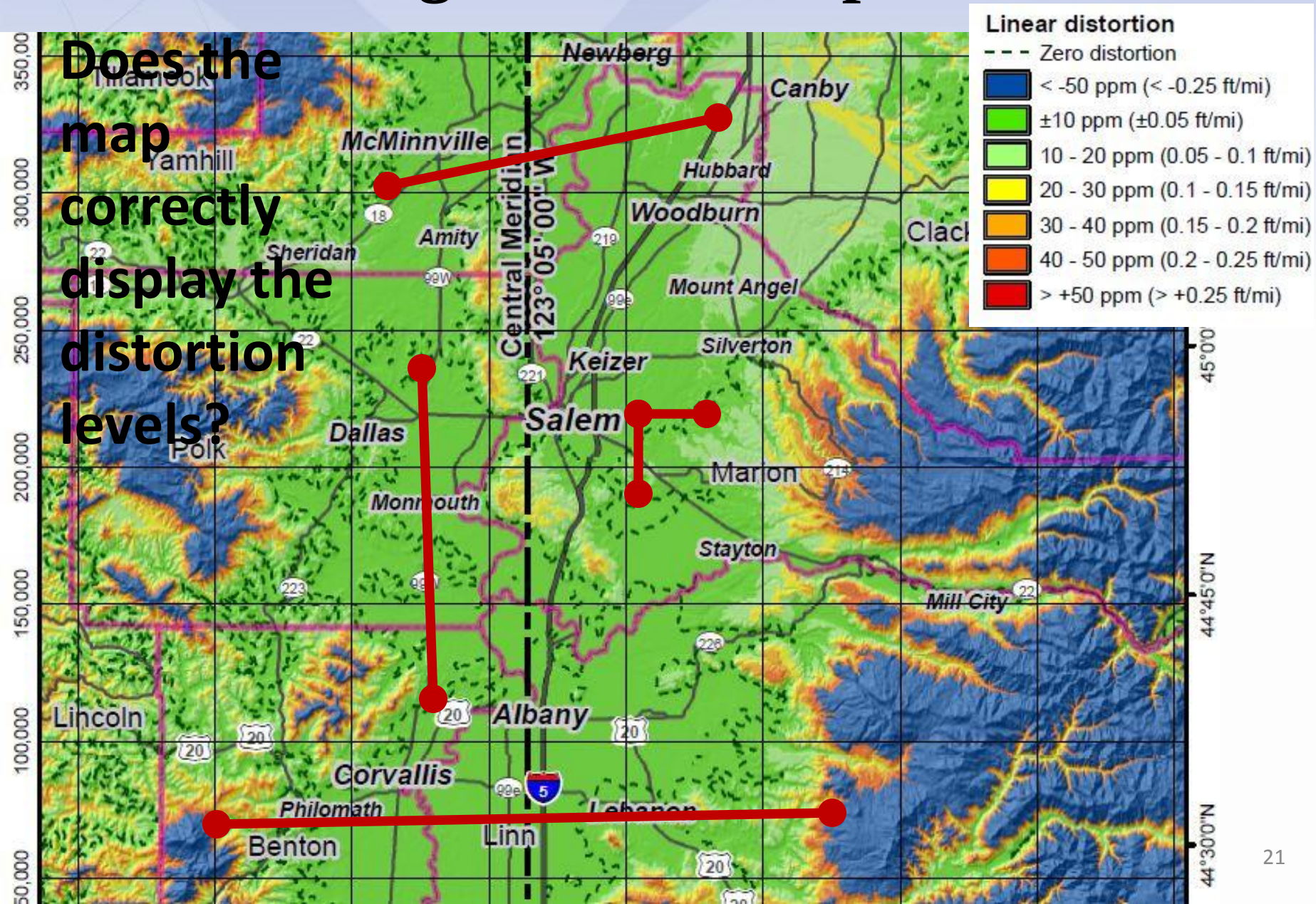
- **Step 4:** Use field tests and calculations to check grid vs ground distances across the projection and determine the actual ppm of distortion.
- Measure short baselines (~ 1500 m)
- Measure medium baselines (~ 5000 m)
- Measure long baselines across entire zone
- **Are YOU HAPPY with the results??? Can you make it better?**

Testing Procedures

- Field Test – Short Lines
  - EDM Base Lines - ~ 1 Mile
- Field Test – Medium Lines
  - EDM Base Lines - ~ 3-5 Miles
- Office Test – Long Lines
  - Calculate between CORS - ~10-75 Miles

Checking the Zone Map Distortion

Does the map correctly display the distortion levels?



Set LDP Zone Coord. On Passive Marks

- **Establish LDP zone coordinates on several passive marks in each zone for local surveyors to check into with GPS and RTN if available.**
  - Use rigorous methods, longer than normal occupation times
  - Publish location and coordinates on website for all to use

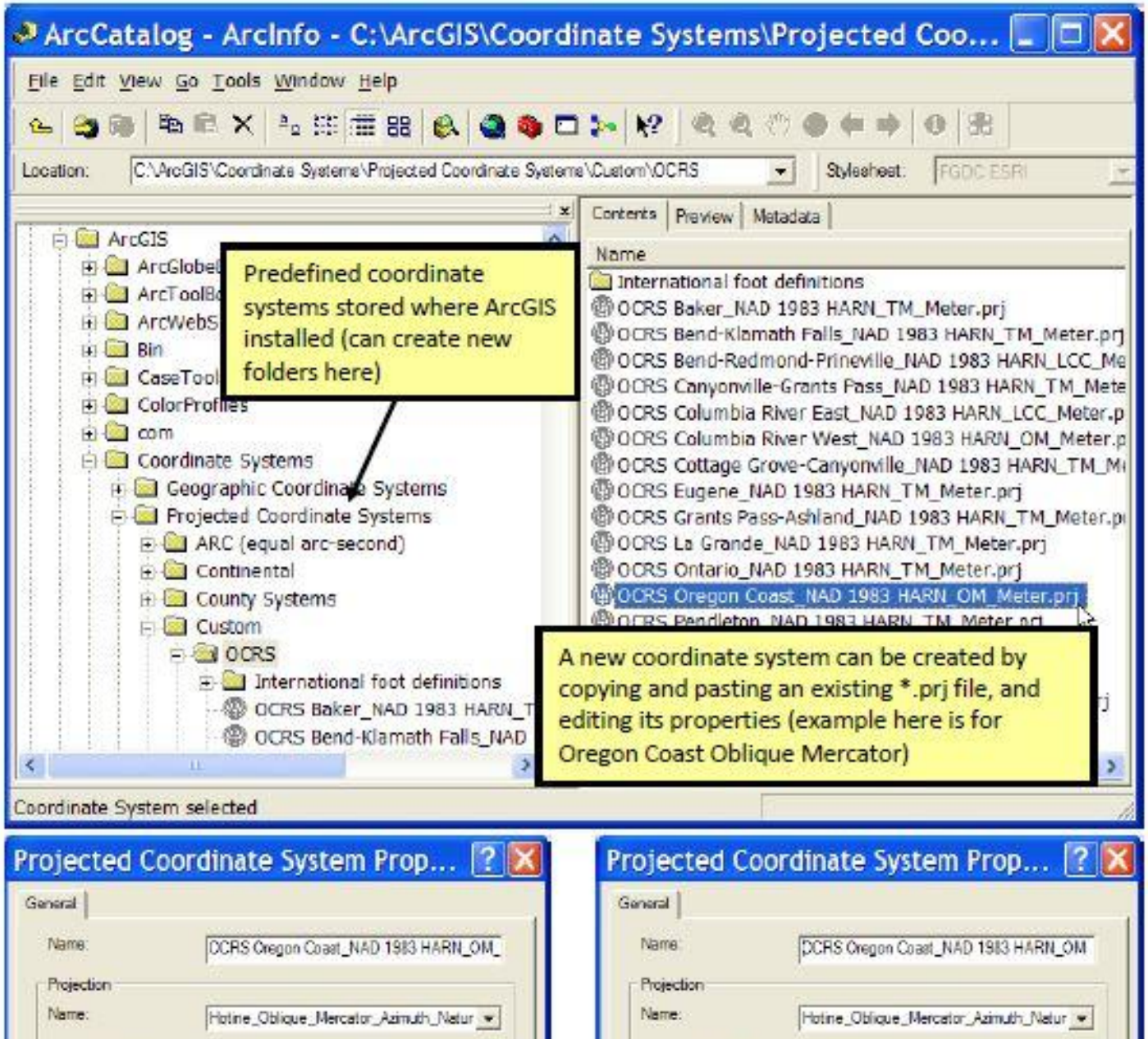
Vendor Software – Inclusion of new zones

- Complete zone design, testing, proofing
- Beta test with actual survey projects
- Commit to no further changes to the zone!
- DOT makes decision to use on State projects
- Complete most zones across the State
- Hold LDP workshop – show and tell
- Place zone parameters on website
- Letter to software vendors to request including in software

Vendor Software – Provide zones parameter file formats

- ESRI GIS projection files (.prj)
  - List in metric and international feet
- Trimble Coord. System Manager files (current.csd)
- Leica Coord. System Manager files (TRFSET.dat)
- Topcon Tools, Blue Marble, Carlson, etc. etc. etc.

Help Users Enter the LDP Parameters into



Make Grid Coord. Available for Checking Parameter Entry into Software

4.2 Checking Software Output Grid Northing's and Easting's

The included table offers the correct grid northing and easting for three points in each OCRS zone. If you have entered the OCRS zone parameters into your vendor's software and successfully created coordinate systems, then, by entering the input lat/long values in the table, your project grid coordinates should match these results. The output data (northing's & easting's) in table 4.2 are carried out to five decimal places in order to check the math formulas used by each vendor. Regardless of the software, match these output values exactly (Trimble output varies in the ~last decimal place for the OM/RSO projections). If you do not match, refer back to section 4.1 and check your OCRS zone parameter input.

Table 4.2

INPUT DATA (From NGS Datasheets)						OUTPUT DATA	
OCRS Zone Name	NGS PID	Designation	Datum	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Baker	QB1363	AIRPORT	NAD 83 (2007)	44 49 57.80936	117 48 54.56244	36980.20833	41437.60083
Baker	QB0884	E 305	NAD 83 (2007)	44 52 07.48389	117 54 26.35126	40986.29136	34152.16275
Baker	QB1364	MASON	NAD 83 (2007)	44 40 24.70946	117 59 40.97048	19299.09877	27201.54461
Bend-Kfalls	DH7225	ORK1 CORS ARP	NAD 83 (CORS)	42 17 19.71674	121 40 09.54146	59862.74501	86655.66105
Bend-Kfalls	DH3761	MDMT CORS ARP	NAD 83 (CORS)	42 25 06.01243	121 13 17.70770	74385.61148	123500.38364
Bend-Kfalls	NY0977	ALTAMONT	NAD 83 (2007)	42 12 32.57089	121 44 50.17150	50997.92871	80225.49733
Bend-Redmond-Prineville	AH2507	REDM CORS ARP	NAD 83 (CORS)	44 15 35.14513	121 08 52.31624	84783.59542	88157.16577
Bend-Redmond-Prineville	QD1644	BEND AIRPORT	NAD 83 (2007)	44 05 37.43097	121 12 11.97934	66327.93549	83738.15165
Bend-Redmond-Prineville	QD1879	SISTERS	NAD 83 (2007)	44 18 20.44566	121 33 21.22192	89927.19462	55588.29029
Canyonville-Grants_Pass	NZ0930	N 748	NAD 83 (2007)	42 37 15.80562	123 22 56.67677	13449.63952	35973.43780
Canyonville-Grants_Pass	AA5139	X 026	NAD 83 (2007)	42 48 41.75301	123 35 45.71429	34650.09185	18512.47686
Canyonville-Grants_Pass	NZ1329	AZAL	NAD 83 (2007)	42 47 56.60859	123 15 10.17963	33226.59339	46586.32144
Columbia_River_East	RD1615	C 719	NAD 83 (2007)	45 36 41.82270	122 01 15.12506	25007.74017	31373.11293
Columbia_River_East	RC1917	MOF	NAD 83 (2007)	45 37 22.73728	121 58 40.65328	26208.05388	34742.89853

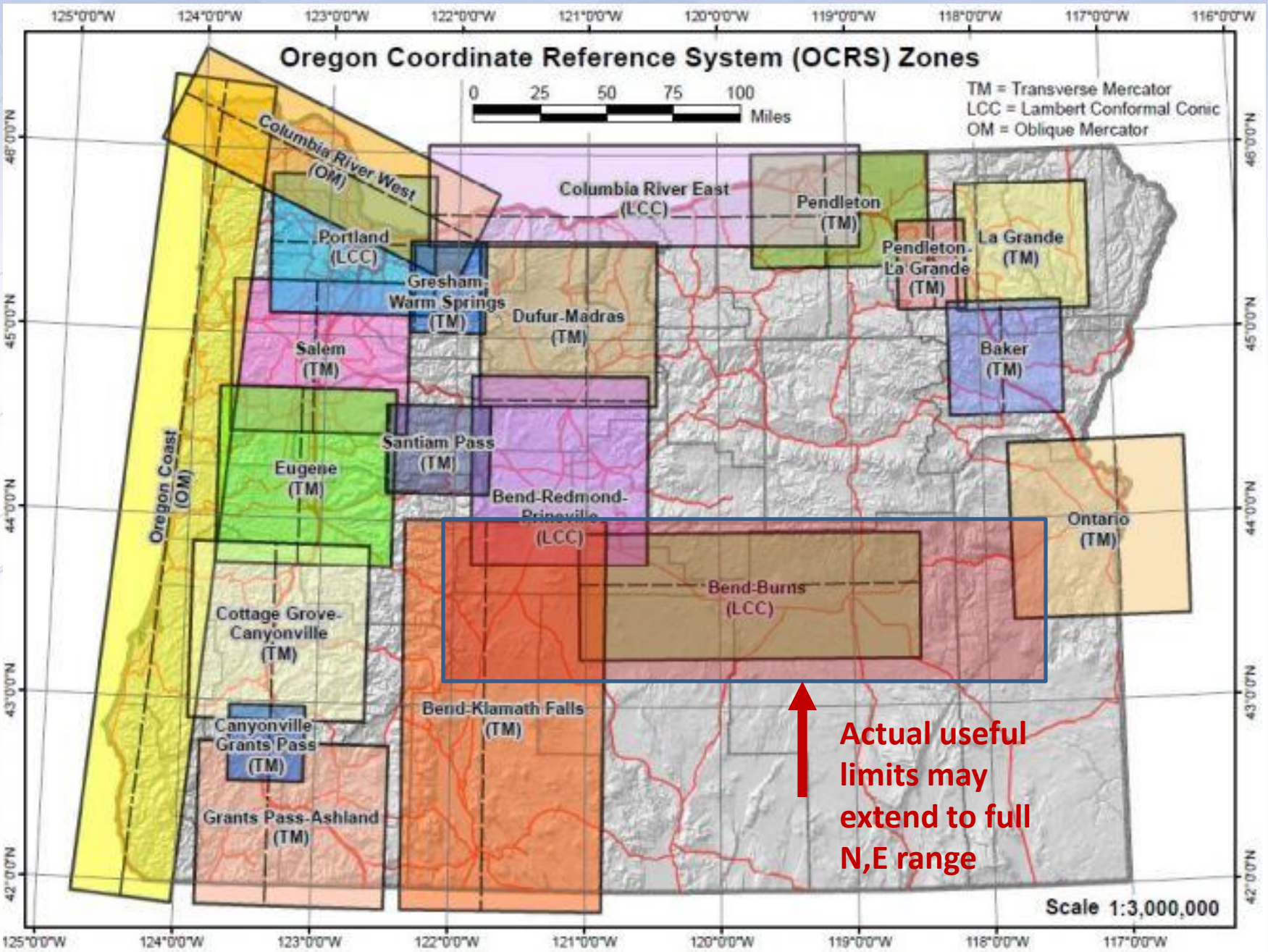
Make the LDPs Easy to Use

- Provide an instruction manual on guidelines for use.
- For entering zone parameters into software.
- For planning projects – how to select an LDP to use for a project.
- Hold an LDP workshop
- Write a project paper
- http://50.18.60.197/OCRSII/Default.aspx

Other Zone Details

- Generally zones should overlap each other if adjacent…
  - Facilitates choosing one when a project crosses a zone boundary
  - Realize that zones are bigger than visually experienced. Only limit is False N & E so don't have negative coordinates.

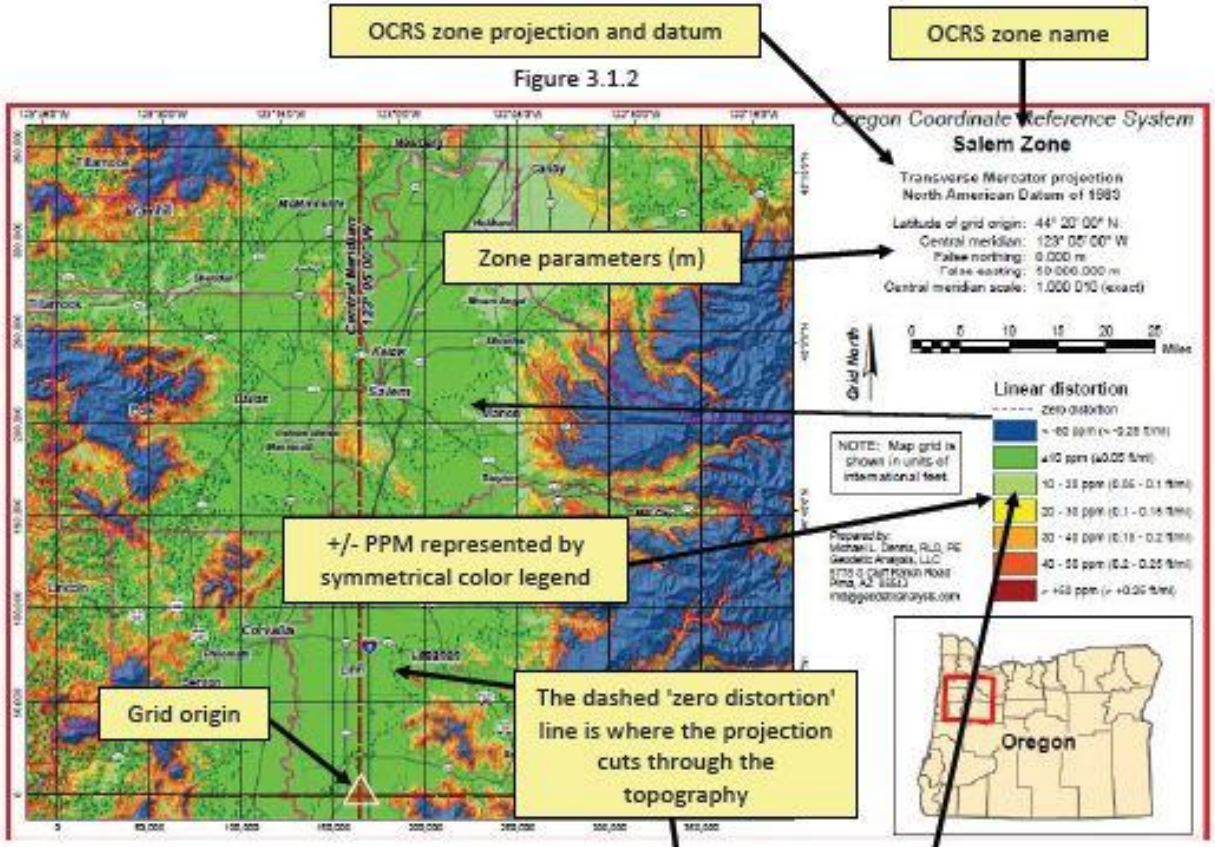
Zone True Size

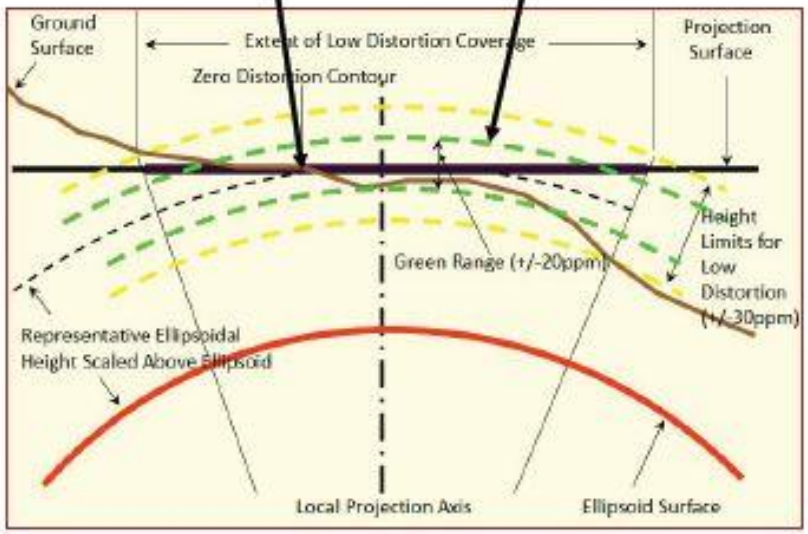


Map Interpretation

- Learn everything about the LDP zone maps to…
  - help you in your work
  - save you time in planning projects
  - Keep you from making wrong assumptions
  - Improve coordinate system understanding
  - Add documentation and meta data to your surveys and maps

Figure 3.1.2


OCRS zone projection and datum
OCRS zone name
Oregon Coordinate Reference System
Salem Zone
Transverse Mercator projection
North American Datum of 1983
Zone parameters (m)
Linear distortion
+/- PPM represented by symmetrical color legend
Grid origin
The dashed 'zero distortion' line is where the projection cuts through the topography
Oregon


Ground Surface
Extent of Low Distortion Coverage
Projection Surface
Zero Distortion Contour
Green Range (+/-20ppm)
Height Limits for Low Distortion (+/-30ppm)
Representative Ellipsoidal Height Scaled Above Ellipsoid
Local Projection Axis
Ellipsoid Surface

Key Things to Remember

- Grid coordinates from any projection are datum dependent, so if you…
  - change the datum understand that the grid N, E, coordinates will change.
  - Elevations (ortho heights) are dependent on the geoid model chosen when using GNSS.
  - Don't mix grid coordinates from different datum even with the same LDP zone.
  - No different than procedures you've commonly followed when using State Plane.

The Best LDPs are the ones…

- That were sufficiently studied to produce the best results for the specified region of concern.
- That are USED …and appreciated!
- That Last along time…because they work so well!
- That are legislated into State law…

NGS Policy and Additions to SPC Systems

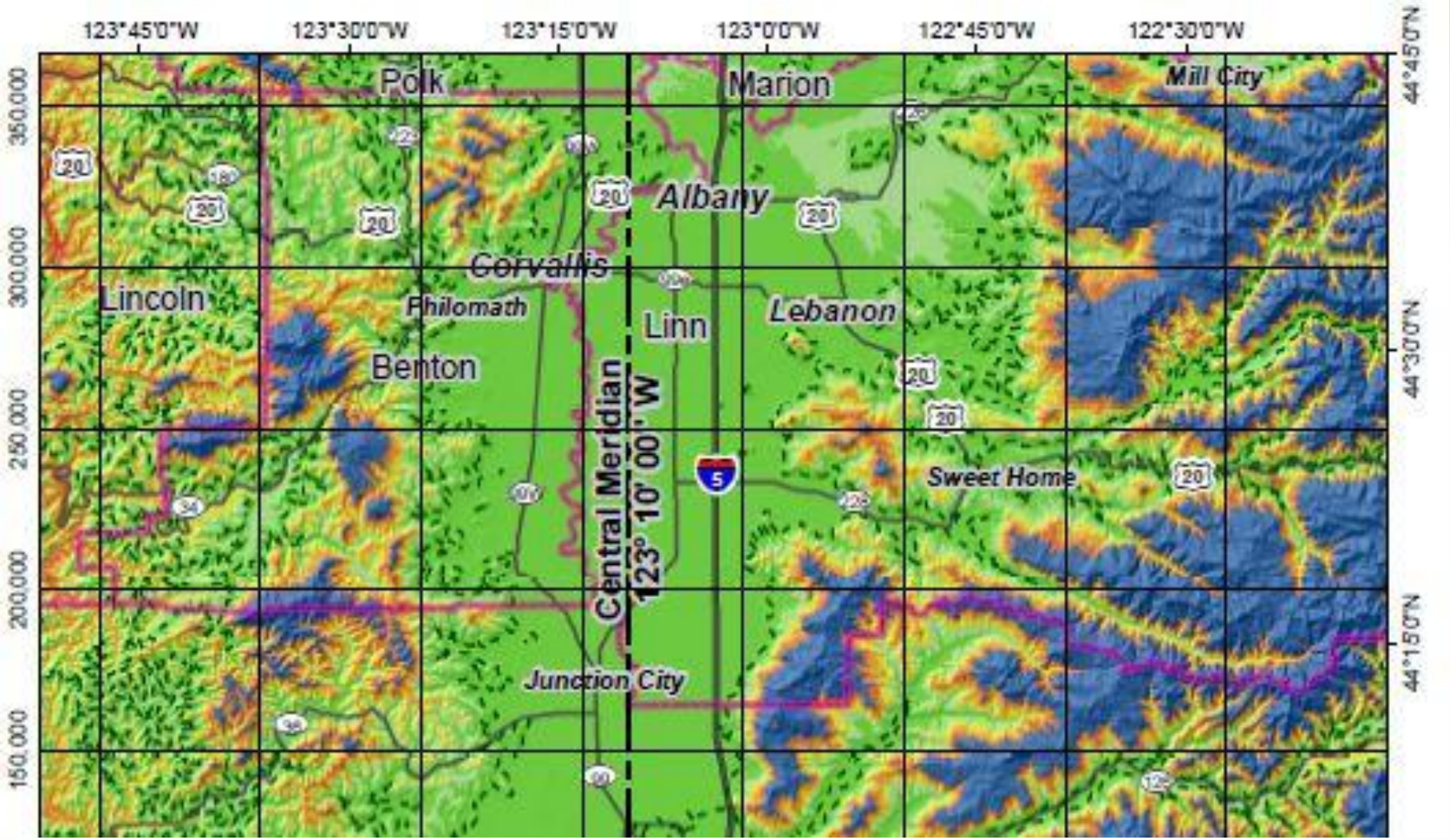
- 1. All requests for changes must be submitted in writing to the Director, NGS, and must be co-signed by those State agencies and organizations most involved in the use, collection, and distribution of spatial data including, but not limited to, the State Department of Transportation, State Office of GIS, and state land surveyor professional organizations. Hereafter these groups are referred to as the "State." Required agencies and organizations will be determined by NGS on a state-by-state basis. A similar request must also be submitted to the U.S. Geological Survey (USGS) to ensure integrity of NSRS with USGS national mapping products and services.
- 2. All new SPC zones or supplemental projections shall use the two basic map projections, the Lambert Conformal Conic or the Mercator (transverse or oblique), defined at the surface of the ellipsoid of the current Datum (Geodetic Reference System 1980 - GRS 80).
- 3. All changes must be adopted by State Law (or State Regulation when such Regulation is regulated by public notices and hearings and no opposition exist). Such Law must include a complete description of the revised SPCS zones and geometric parameters. A specified conversion factor between meters and feet (U.S. Survey or International) is strongly recommended to be included in the legislation. NGS will publish coordinates only in those legislated units.
- 4. Zones will continue to be defined by International, State and county boundaries, and by the counties contained therein. (See Federal Register Notice "Policy on Publication of Plane Coordinates," Vol. 42, Nol. 57, page 15943-15944, published March 24, 1977.)
- 5. SPCS changes will ensure that the resulting coordinate differences are sufficiently large (by at least 10,000 meters) to ensure that no confusion will exist with the current NAD 83 coordinate values.

http://www.ngs.noaa.gov/INFO/Policy/SPCS4.html

- 6. A naming convention shall be developed that ensures a distinct labeling between the existing and revised new coordinate zones.
- 7. Should NGS estimate significant expenses resulting from changes to the existing SPCS, NGS may require State reimbursement. These costs would be for coordinate conversion, data base extraction and publication software required to support computation, publication and distribution of new coordinate values as part of NSRS.
- 8. To facilitate public awareness, the State shall develop an education program that includes an article detailing the rationale for the development of the changes, the process of review and examination of the issues, the final design criteria, and a workshop or seminar to be presented at a State-wide surveying and mapping conference . The article shall be submitted for publication in one or more surveying and mapping periodicals (e.g., American Congress on Surveying and Mapping Bulletin, Professional Surveyor, or P.O.B. magazines). In addition, this article will be made available on the web sites of the sponsoring agencies defined as the "State." Any requests for technical support from NGS requiring travel expenses for NGS personnel shall be reimbursed by the State.

DOES NOT ENDORSE BUT UNDERSTANDS THE NEED

Questions?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