The Wisconsin County Coordinate System:

Redefinition of the Foundation

WLIA
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WLIA Coordinate Systems Task Force

- Today’s Presentation:
  - Al Vonderohe – WCCS: Redesign Objectives, Strategy, and Methodology
  - John Ellingson – WCCS: Testing the Redesign
  - Mike Koutnik – GIS applications
  - Ted Koch – Summary & Questions
WLIA Coordinate Systems Task Force

• **Mission:**
  • Analyze and document the foundations of the WCCS
  • Investigate, analyze and document software implementations of WCCS
  • Investigate the redesign of the WCCS
  • Register WCCS with standards setting organization
  • Document WCCS proceedings
  • Develop user-focused documentation
  • Evaluate and make recommendations regarding statutory changes
  • Present TF recommendations to WLIA Board
WLIA Coordinate Systems Task Force

- Task Force Members:
  - Tom Bushy  ESRI
  - Diann Danielsen  Dane County
  - John Ellingson  Jackson County
  - Pat Ford  Brown County
  - Gene Hafermann  WI Dept of Transportation
  - David Hart UW-Madison  Sea Grant
  - Ted Koch State Cartographer, Chair
  - Mike Koutnik  ESRI
  - John Laedlein  WI Dept of Natural Resources
  - Gerald Mahun  Madison Area Technical College
  - David Moyer, Acting State Advisor  Nat’l Geodetic Survey
  - Karl Sandsness Ayres Associates
  - Glen Schaefer  WI Dept of Transportation
  - Jerry Sullivan  WI Dept of Administration
  - Al Vonderohe  UW-Madison, Dep’t of Civil & Environmental Engineering
  - Jay Yearwood  City of Appleton
  - AJ Wortley  State Cartographer’s Office
Task Force Accomplishments – Past Year

- 6 meetings in past 12 months
- Task Force decision to move ahead with redesign
- WLIB directs Strategic Initiative Grant to fund redesign
- Jackson County administers redesign contract
- Initial redesign work is completed and tested
- Various public presentations on Task Force work
- Discussions on “next steps” regarding documentation & education
From

WCCS (Wisconsin County Coordinate System)

To

WISCRS (Wisconsin County Reference Systems)

Alan Vonderohe
Fundamental Descriptors of Position

Ellipsoid
Meridian of Longitude
Prime Meridian
Parallel of Latitude

Latitude ($\phi_P$) and Longitude ($\lambda_P$) of point P
Elements of an Ellipse

- **Major Axis**
  - $a$ = Semi-Major Axis
- **Minor Axis**
  - $b$ = Semi-Minor Axis

Rotate about minor axis to generate oblate spheroid.

Spheroid used for current national geodetic datum (NAD83) is named “GRS 80”:  
- $a = 6378137.0$ m  
- $b = 6356752.3141403$ m
Computational and Visualization Problem

- Latitude / Longitude are angular, not rectangular coordinates.
- Ellipsoid surface cannot be cut and laid flat.
- Latitude / Longitude must be projected to a “developable” surface to obtain rectangular coordinates.
Developable Surfaces

- Cylinder
- Cone
- Plane
One Way to Conceptualize “Projection”

Points on the ellipsoid are projected to the projection surface by straight lines from the center of the ellipsoid.

Note scale factor and how it varies across the projection surface.

Note: Some map projections are purely mathematical and have no graphical counterpart.
Problem: Length distortion occurs when projecting from:
- Ground (Earth) to ellipsoid
- Ellipsoid to projection surface

Measurements are made here

GIS spatial databases and infrastructure designs are referenced here
Ground-to-Grid

- Two step process to obtain grid (map projection) distances from ground distances:

\[ D_{ellipsoid} = (D_{ground})(EllipsoidFactor) \]

- Or

\[ D_{grid} = (D_{ellipsoid})(ScaleFactor) \]

\[ D_{grid} = (D_{ground})(EllipsoidFactor)(ScaleFactor) \]
Wisconsin County Coordinates

• Original WCCS Objective:
  1. Make differences between ground distances and grid distances negligible for most applications.

• Original Design Strategy:
  1. Restrict extent of each projection so scale factor is approximately equal to one everywhere.
  2. For each projection, enlarge the ellipsoid by adding an amount that brings it to about the mean elevation of the terrain. This causes the ellipsoid factor to be approximately equal to one everywhere.
Wisconsin County Coordinates

72 Counties
59 Coordinate Systems
24 Lambert
35 Transverse Mercator
Lambert Conformal Conical Projection

Scale variation is greater north-south than east-west.
Lambert Conformal Conical Projection

Projection Parameters:

- $\lambda_0$ (longitude of central meridian)
- $\phi_1$, $\phi_2$ (latitudes of standard parallels)
- $\phi_0$, $X_0, Y_0$ (latitude, false easting, false northing of the coordinate origin)

Alternative to $\phi_1$, $\phi_2$ is $\phi_0, k_0$ (latitude and scale factor at central parallel).
Scale variation is greater east-west than north-south.
Transverse Mercator Projection

Projection Parameters:

- \( \lambda_0 \) (longitude of central meridian)
- \( k_0 \) (scale factor along central meridian)
- \( \phi_0, X_0, Y_0 \) (latitude, false easting, false northing of the coordinate origin)
Problem:
- Each projection has its own ellipsoid.
- This makes it seem like each projection has its own datum.
- Confusion abounds.
WLIA Task Force

• In 2004, WLIA formed the Wisconsin Coordinate Systems Task Force to address this and other spatial referencing issues.
• Ultimately, the Task Force recommended redesign of the system, established criteria, and obtained funding.
Redesign Objectives

1. Redesign the coordinate systems so there is no need to enlarge the ellipsoid.
   - There will be only one ellipsoid (GRS80) for everyone.
2. Redesigned coordinates should not differ by more than 5mm from the originals anywhere on any projection.
   - Legacy data will be preserved.
   - Existing and new data can be combined without transforming either.
Redesign Strategy

1. Multiply scale factor on Central Meridian (Transverse Mercator) or Central Parallel (Lambert) by inverse of ellipsoid factor to obtain provisional scale factor.
   - Causes ellipsoid factor and scale factor to be approximate reciprocals of one another, so when they are multiplied together the result is approximately equal to one.

2. Adjust false northing, false easting, and provisional scale factor to account for effects of differences of the two ellipsoids (GRS80 and enlarged).
Redesign Methodology

• Methodology:
  1. Use DNR statewide map to obtain boundaries for each projection.
  2. Generate a 0.5-mile grid of test points within a 2-mile buffer for each projection.
Redesign Methodology

Methodology:

3. Compute provisional scale factor for each projection.
4. Using provisional scale factor, compute provisional county coordinates for each grid point.
5. Compute original county coordinates for each grid point.
6. Develop observation equations for each grid point:

\[
(E_{\text{original}} - E_o) + \nu_{E\text{original}} = S(E_{\text{provisional}} - E_o) + \Delta E_o
\]

\[
(N_{\text{original}} - N_o) + \nu_{N\text{original}} = S(N_{\text{provisional}} - N_o) + \Delta N_o
\]
Redesign Methodology

- Methodology:
  7. Compute least squares solution of about 10,000 equations for each projection to obtain shifts in false northing and false easting, and multiplier for provisional scale factor.
  8. Final Transverse Mercator parameters are:

\[
\begin{align*}
\lambda_{o(\text{redesigned})} &= \lambda_{o(\text{original})} ; \\
\phi_{o(\text{redesigned})} &= \phi_{o(\text{original})} ; \\
k_{o(\text{redesigned})} &= k_{o(\text{provisional})} \times S ; \\
E_{o(\text{redesigned})} &= E_{o(\text{original})} + \Delta E_o ; \\
N_{o(\text{redesigned})} &= N_{o(\text{original})} + \Delta N_o
\end{align*}
\]

Number of Transverse Mercator parameters is reduced from 7 to 5 (no need for design elevation and geoidal separation).
Redesign Methodology

- Methodology:
  9. Final Lambert parameters are:

\[
\begin{align*}
\lambda_{o(\text{redesigned})} &= \lambda_{o(\text{original})} ; \\
\phi_{o(\text{redesigned})} &= \phi_{o(\text{original})} ; \\
k_{o(\text{redesigned})} &= k_{o(\text{provisional})} * S ; \\
E_{o(\text{redesigned})} &= E_{o(\text{original})} + \Delta E_o ; \\
N_{o(\text{redesigned})} &= N_{o(\text{original})} + \Delta N_o
\end{align*}
\]

- Number of Lambert parameters is reduced from 8 to 5.
- \(\phi_{o(\text{original})}\) is computed from \(\phi_{1(\text{original})}\) and \(\phi_{2(\text{original})}\).
- Coordinate origin is shifted to \(\phi_o, \lambda_o\).
- \(N_{o(\text{original})}\) at new coordinate origin is computed, not given.
Redesign Methodology

• **Methodology:**
  10. Compute differences between redesigned and original coordinates at each grid point.
  11. Find maximum shifts in northing and easting to check against 5mm tolerance.
  12. Prepare isoline (contour) maps of coordinate shifts.
Redesign Results

Results:

• All coordinate systems meet the redesign criterion:
  • All coordinate shifts are less than 5mm.
  • Typical coordinate shifts range from –3mm to +3mm.
• Some counties have maximum shifts of less than 1mm.
• Maximum shifts are in Oneida and Vilas (Lambert) and Ashland and Forest (Transverse Mercator).
Coordinate Shifts

Buffalo County (Typical Transverse Mercator)

Shift in Easting (mm)  
Shift in Northing (mm)
Coordinate Shifts

Forest County (Worst-Case Transverse Mercator)

Shift in Easting (mm)

Shift in Northing (mm)
Coordinate Shifts

Burnett County (Typical Lambert)

Shift in Easting (mm)

Shift in Northing (mm)
Coordinate Shifts

Vilas County (Worst-Case Lambert)

Shift in Easting (mm)

Shift in Northing (mm)
Status

• Validation:
  • Independent testing by four individuals using various software packages and programming techniques.
  • All have concluded that the redesign meets the 5mm criterion.
• Draft final report under review.
  • Final submittal during March.
The Task Force has decided:

- To retain the name “WCCS (Wisconsin County Coordinate System)” for the original.
- To name the redesigned “WISCRS (Wisconsin County Reference Systems)”.  
  Individual county systems are suggested to be referred to as “WISCRS, Dane County”, for example.
Wisconsin County Coordinate System

Testing the Redesign

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TO VIEW COORDINATE TEST DATA:

• Go To: www.sco.wisc.edu
• Click on: Coordinate Systems
• Click on: Task Force
• Click on: County Coordinate Test Point Data
  (Listed under Task Force Documents)
Using WISCRS in ArcGIS Desktop
Prototype of access to WISCRS coordinate systems in ArcCatalog
Building a WISCRS .prj

- Geographic COORDYS
  - All counties use NAD 83 HARN
- Projected COORDSYS
  - Unique to each county
WISCRS Geographic Coordsys

- Specified as NAD 83 HARN
- Same for all counties
WISCRS Projected Coordsys
Ex: Lambert Conic

- Latitudes same for:
  - Latitude of Origin
  - Both standard parallels
- Scale factors can be greater than 1
ArcMap Projections
WISCRS Dane (Foot US) to WTM 27 (meters)

On-the-fly Projection

Setting the transformation method
Projecting WISCRS NAD 1983 HARN Dane (US Foot) to WTM NAD 27 (Meter)
(Coordinate Difference in Meters, test point - projected point)

* Delta X: -0.0014 M
Delta Y: -0.0013 M

Delta X: 0.0012 M *
Delta Y: 0.0022 M
Questions?