Grid to Ground

Presented By:

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State Plane Coordinates (SPCS)

- Specific system for each state
- Some States divided into multiple zones with different grid systems for each zone
- Ohio has two zones; north and south

State Plane Coordinates – Units

NAD 27 – Coordinates in U.S. Survey Feet

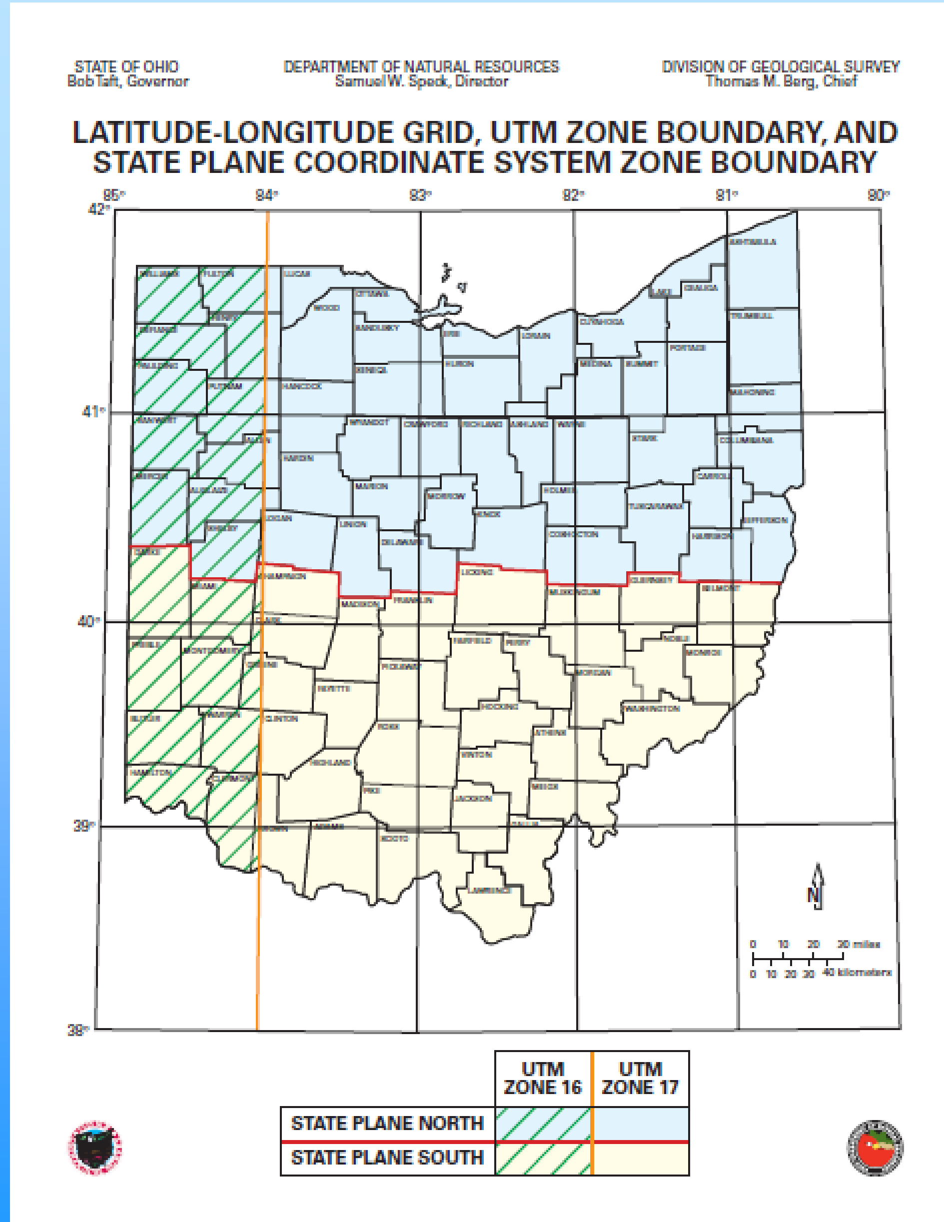
NAD 83 – Coordinates Metric w/State Defined Foot Conversions

1 meter = 3.280833333 U.S. Survey Feet

1 meter = 3.280839895 International Feet

Difference is ~ 1:500,000

U.S. Survey foot used in Ohio


STATE OF OHIO
Bob Taft, Governor
DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director
DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief
LATITUDE-LONGITUDE GRID, UTM ZONE BOUNDARY, AND
STATE PLANE COORDINATE SYSTEM ZONE BOUNDARY
85°
84°
83°
82°
81°
80°
42°
41°
40°
39°
38°
N
0 10 20 30 miles
0 10 20 30 40 kilometers
UTM ZONE 16
UTM ZONE 17
STATE PLANE NORTH
STATE PLANE SOUTH

NAD 27 to NAD 83 (1986) Position and Coordinate Shifts

Geodetic vs State Plane

Clark 1928

Geodetic Position

Datum	Latitude	Longitude
NAD 27	40° 03’ 09.89400”	82° 58’ 35.2650”
NAD 83	40° 03’ 10.12158”	82° 58’ 34.92303”
Difference	00° 00’ 00.22758”	00°00’ 00.34197”

North 23.06 feet East 25.17 feet

Overall position shift of 34.14 feet NE

State Plane Coordinates

Datum	Northing (Y)	Easting (X)
NAD 27	748,005.80 ft.	1,866,612.19 ft.
NAD 83	748,034.32 ft.	1,835,142.41 ft.
Difference	+37.52 ft.	-31,469.78 ft.

Overall shift is 6 miles East!

Datum Transformation Software

Federally produced datum transformation software is available free of charge for NOAA's National Geodetic Survey web site:

http://www.ngs.noaa.gov/TOOLS/

NADCON – NAD 83 vs NAD 27
VERTCON – NAVD 88 vs NGVD 29
HTDP – between a variety of reference frames
UTMS – UTM vs lat./long.
SPCS83 – State Plane 83 vs lat./long.
GPPCGP – State Plane 27 vs lat./long.

State Plane Coordinates

What are they?

Where did they come from?

Why do we need them?

Who uses them?

What are they?

Ohio Surveying Laws defines what we call State Plane Coordinates.

Ohio's State Plane Coordinate System is a means to report survey courses (Direction and Distances) and the resulting coordinate values on a single plane. This allows for conformity between surveys, preservation of data and a means of dealing with problems associated with the earth's curvature.

Where did they come from?

The Coast and Geodetic Survey developed a projection system unique to each state.

These systems would allow cartesian coordinates, or conventional surveying methods (departures, latitudes, and elevations) to be expressed on a single flat plane. Each state's system was established using either the Transverse Mercator (Cylindrical) or the Lambert Conformal (Cone) projection. The choice of which system and the number of systems for each state dealt mainly with the shape and size of the state. Minimal differences between ground (cartesian) and grid distances was desirable. Maximum distortion was set at 1 in 10,000. Holding this proposed adjustment limit meant Ohio needed two Zones. Lambert was chosen and in 1933 the system was adopted into law. The System was later revised and created two new systems. The old system is now known as the Ohio Coordinate System of 1927 and the new as Ohio Coordinate System of 1983.

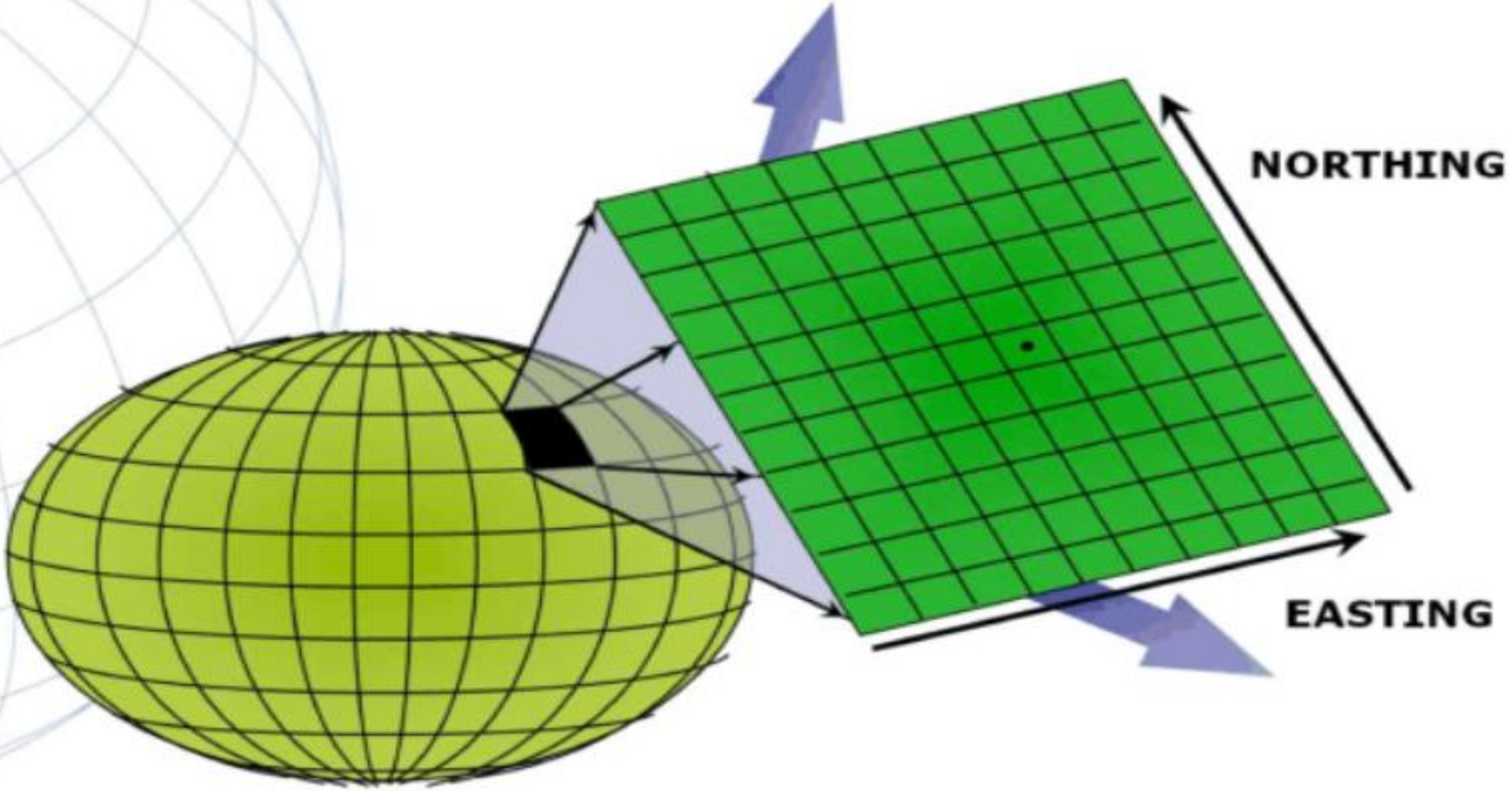
Why do we need them?

Why we need State Plane Coordinate Systems today is seemingly no different from the needs of those whom envisioned, developed, and implemented the systems over 70 years ago. We reside and work almost entirely on the earth's surface but would like to deal mathematically with a flat surface when it comes to surveying. Technological advancements, accumulation of survey data and the need to interrelate data over ever larger and larger areas.

Who uses them?

Everyone in the surveying profession. Well, at least in some way or another we all do. State Plane Coordinates are the basis for nearly all Government and Private GIS Systems. In the past the Geodetic values (Latitude, Longitude, and Elevation) was an acceptable means to report the position of a point or monument. Now, more and more governmental agencies require at least some reporting in State Plane Coordinates for construction projects, subdivisions, and boundary surveys. If you are not using the system now, you will likely need to in the near future.

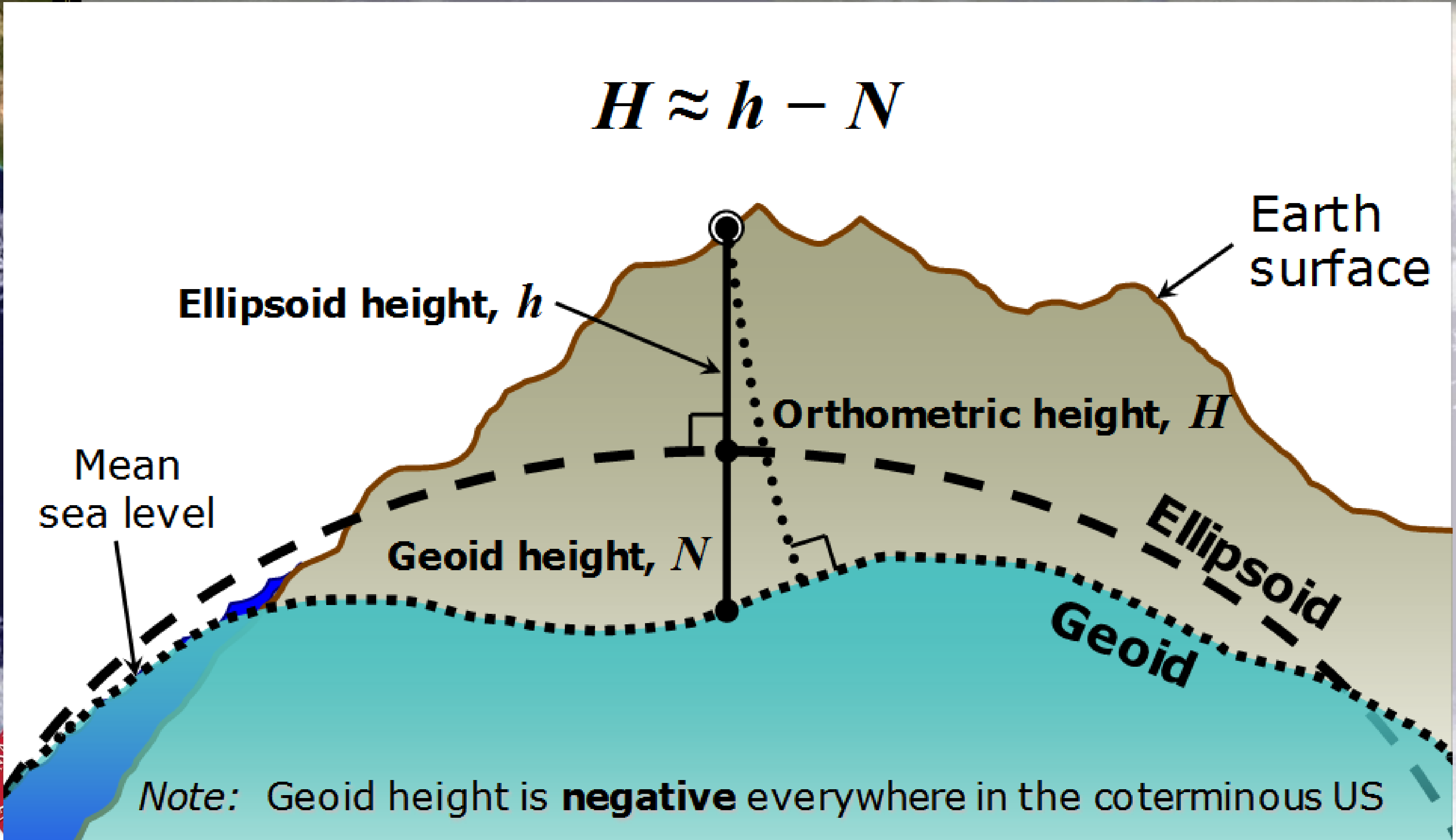
So What Is A Projection



Map Projection

A Map Projection converts the data associated with a given point by projecting from one surface to another. Measurements taken on the earth's surface called ground distances and surface coordinates are converted to ellipsoidal distances and coordinates. Ellipsoidal data is further converted (projected onto the flat surface) to grid distances and coordinates. Although the mathematics involved with these conversions can be completed using a scientific calculator the process from ground to grid is much easier than grid to ground. We will not cover the formulas, but instead refer you to published articles and books covering the topic. Here in Ohio, our Map projection system consist of two zones, North or South. Both zones are Lambert Conformal (Cone) projections, utilizing a submerged cone and the mathematical shape used to best represent the earth's surface (Ellipsoid). Two zones were required to limit distortion to less then the 1 in 10,000 originally proposed. However there are many people, businesses, and public agencies attempting to create an alternative system using a single zone. Agencies such as ODOT frequently have large scale projects located in both zones causing confusion. Also the maintenance of two zones creates problems for statewide GIS data. A single zone would alleviate some problems but of course, create others.

Ground vs Geodetic vs Grid



Three Distances

"GROUND" DISTANCE = NORMAL TO GRAVITY BETWEEN TWO POINTS

"GEODETIC" DISTANCE = ALONG THE ELLIPSOID

"GRID" DISTANCE = ALONG THE MAP PROJECTION SURFACE

PROJECTED COORDINATES ARE <u>ALWAYS</u> DISTORTED!!!

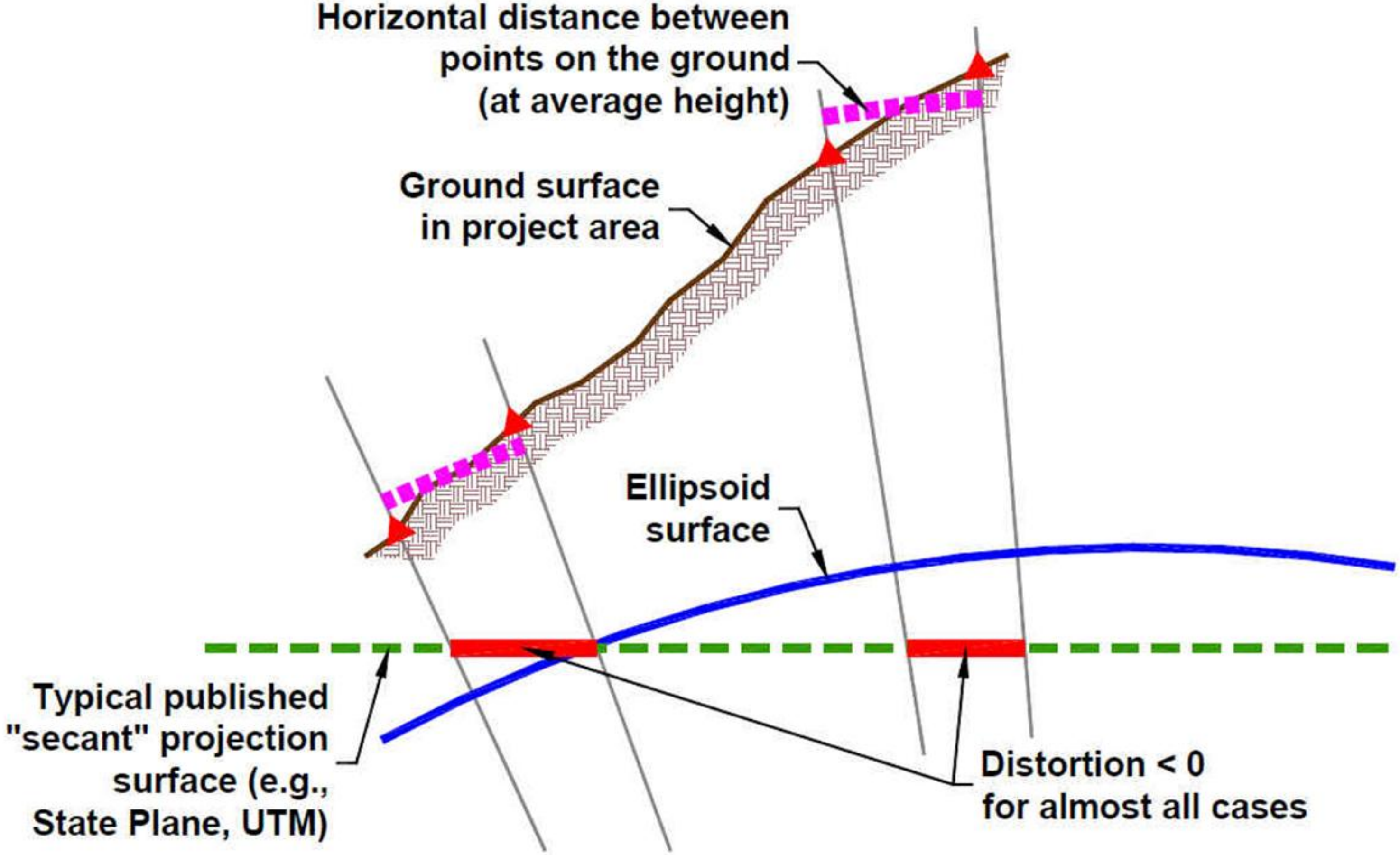
Definitions

GRID SCALE Factor: Multiplier to change geodetic distances based on the Earth model (ellipsoid) to the grid plane.

ELEVATION Factor (a.k.a. Sea Level Reduction or Ellipsoid Reduction Factor): Multiplier to change horizontal ground distances to geodetic (ellipsoid) distances

GRID-ELEVATION or COMBINED Factor: Grid Scale Factor times the Elevation Factor. This factor changes horizontal ground distances to grid distances

Linear distortion due to ground height above ellipsoid



Linear distortion due to Earth curvature

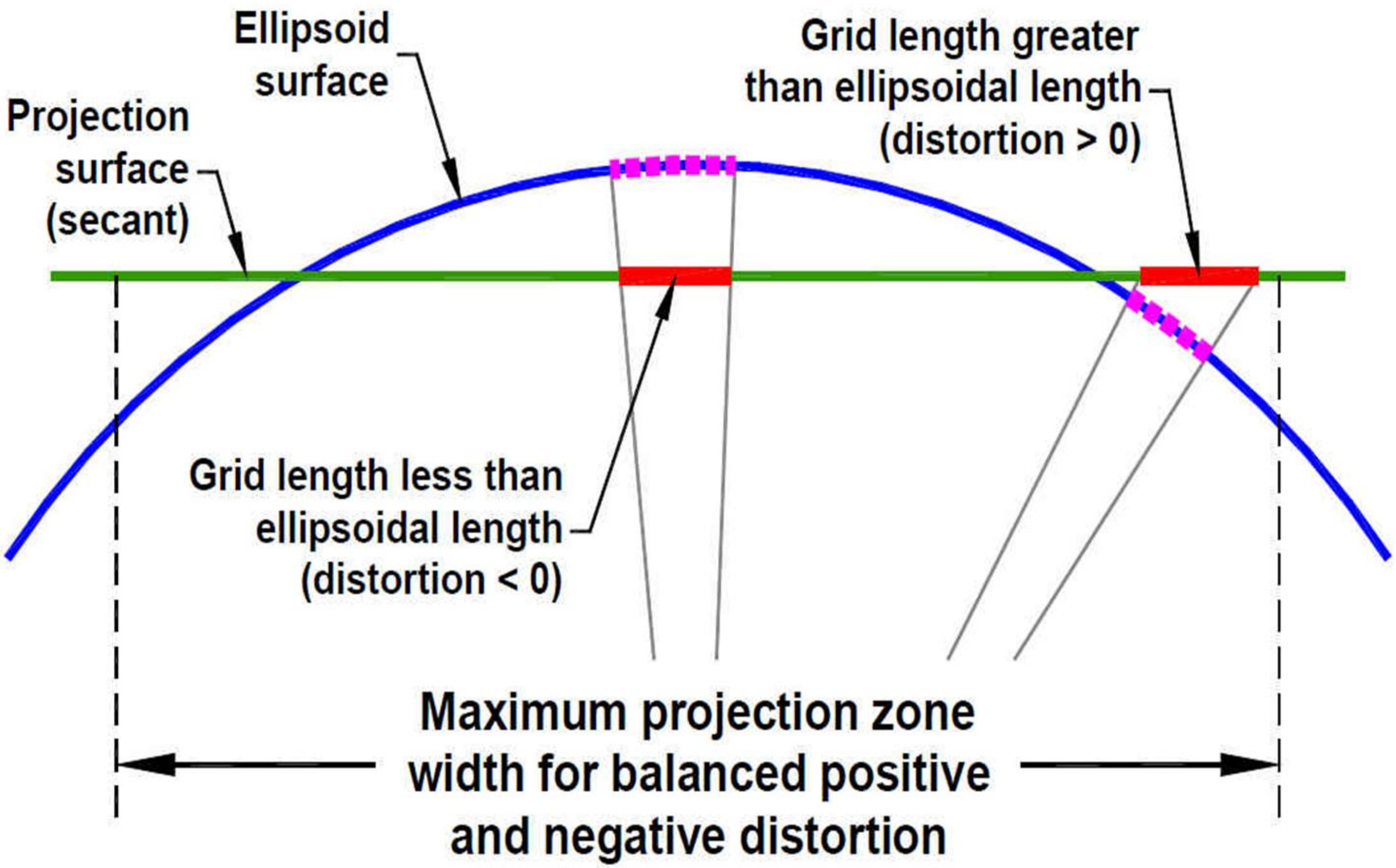
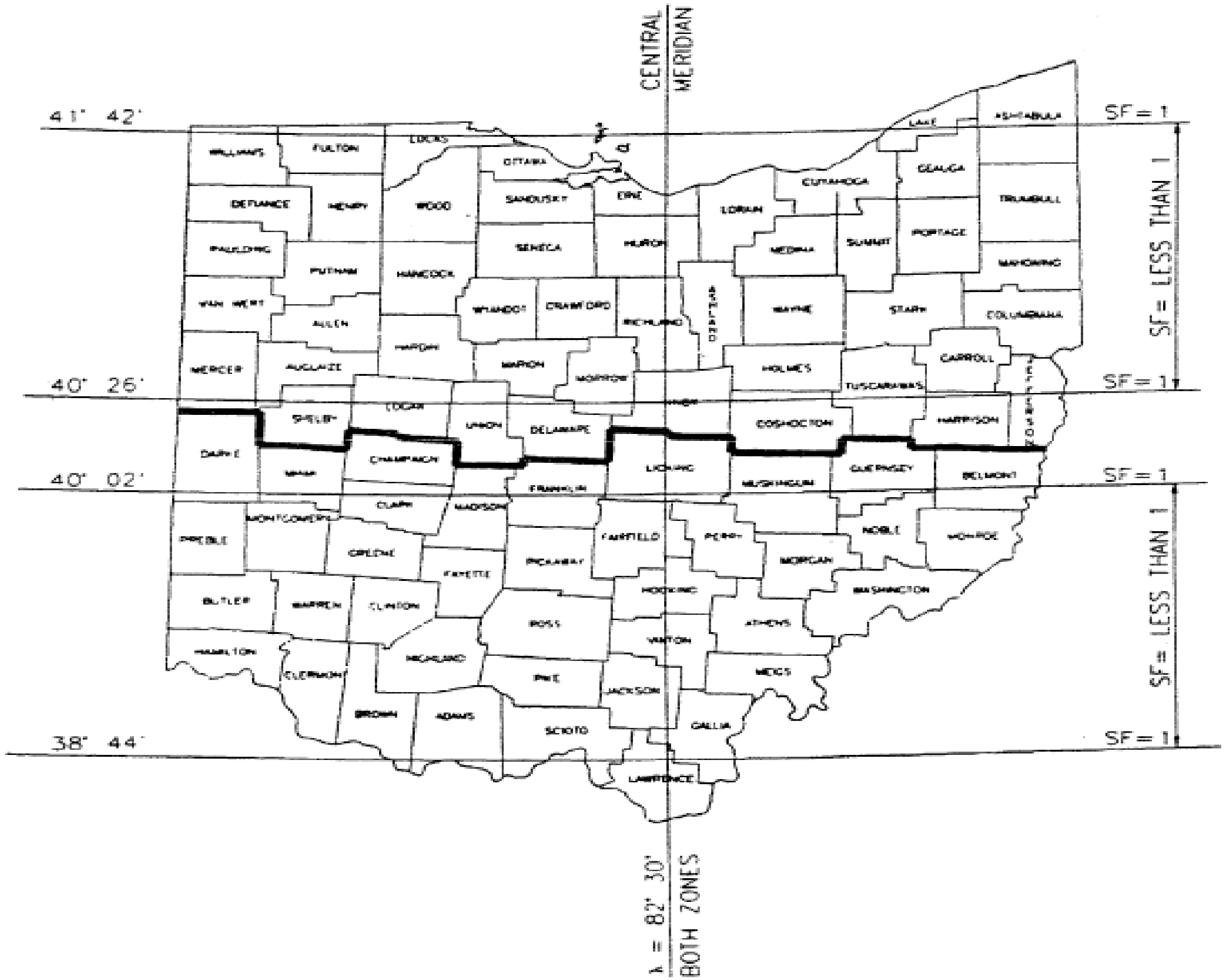


Figure 14

OHIO COORDINATE ZONES AND SCALE FACTORS



Dark line along county lines divides N. and S. zones.
Scale Factor is greater than 1 outside SF=1 lines.

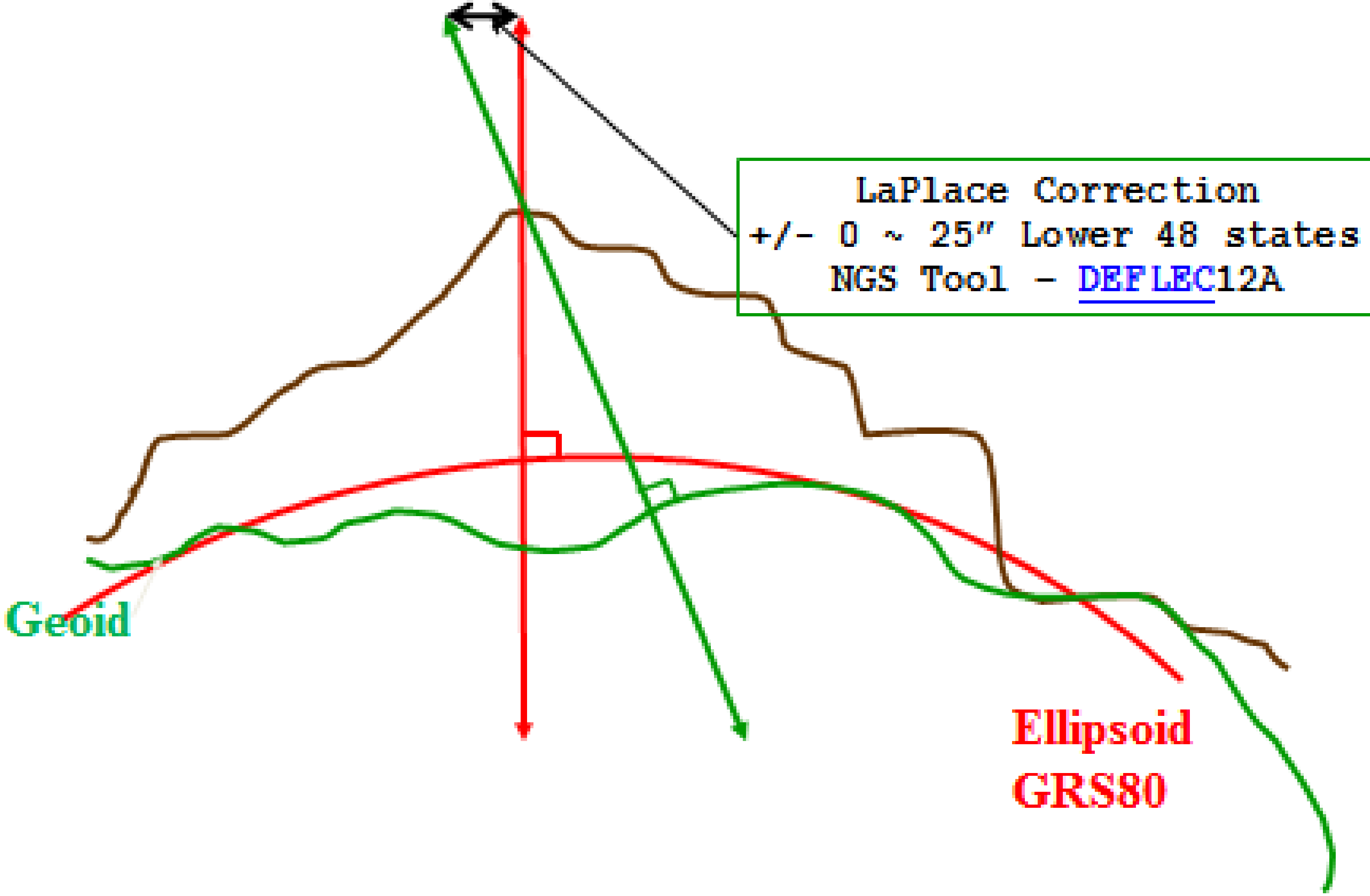
AZIMUTH RELATIONSHIP

"True" Azimuth – Derived from astronomic observations (e.g. Solar/Polaris) –this can usually be considered the same as a geodetic azimuth.

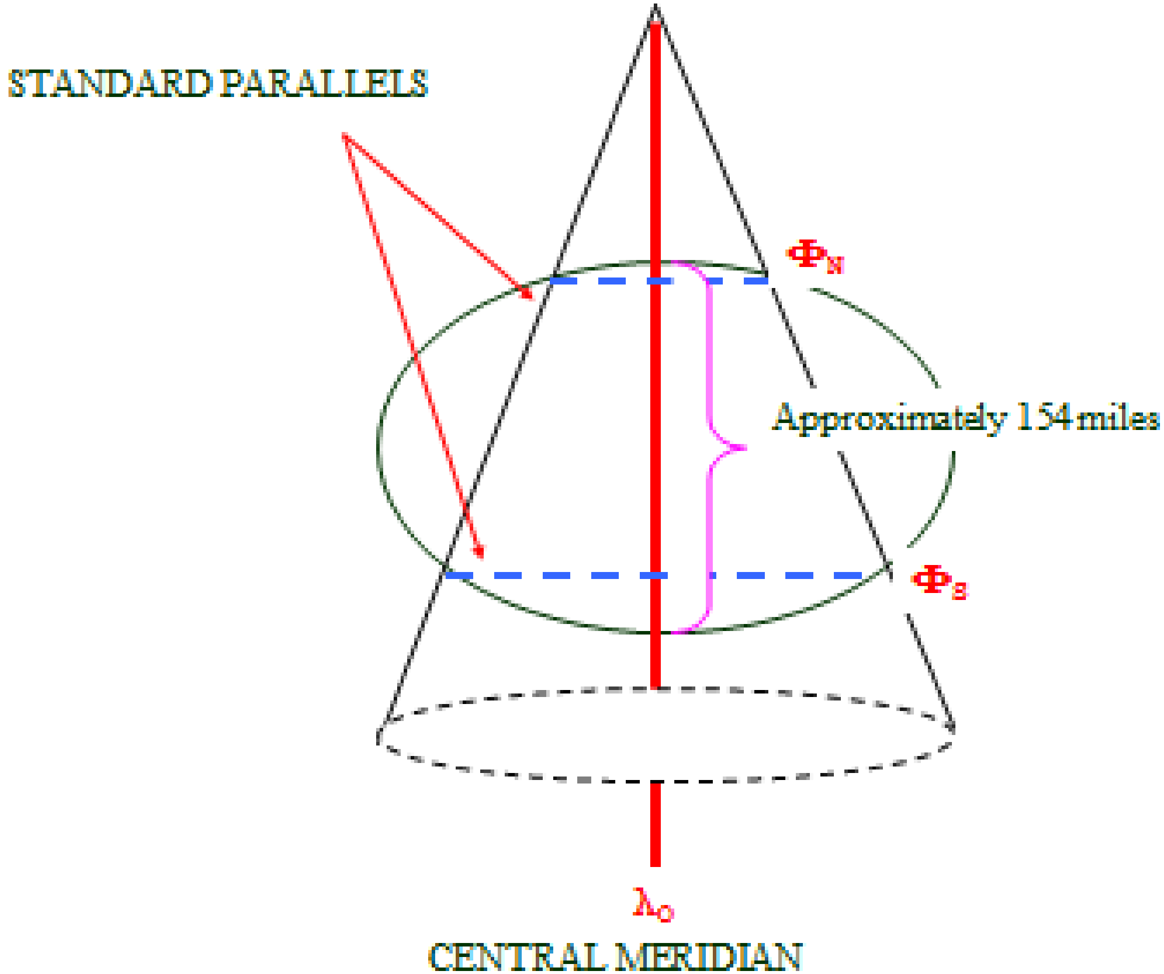
Geodetic Azimuth – Derived from the inverse between two points of known latitude and longitude, or from a LaPlace corrected astronomic azimuth or a grid azimuth with the mapping angle (α) applied

Grid Azimuth – Derived from the inverse between two points defined in northing & easting, or from a geodetic azimuth - the mapping angle (e.g. State Plane, UTM, local grid coordinates)

ELLIPSOID - GEOID RELATIONSHIP

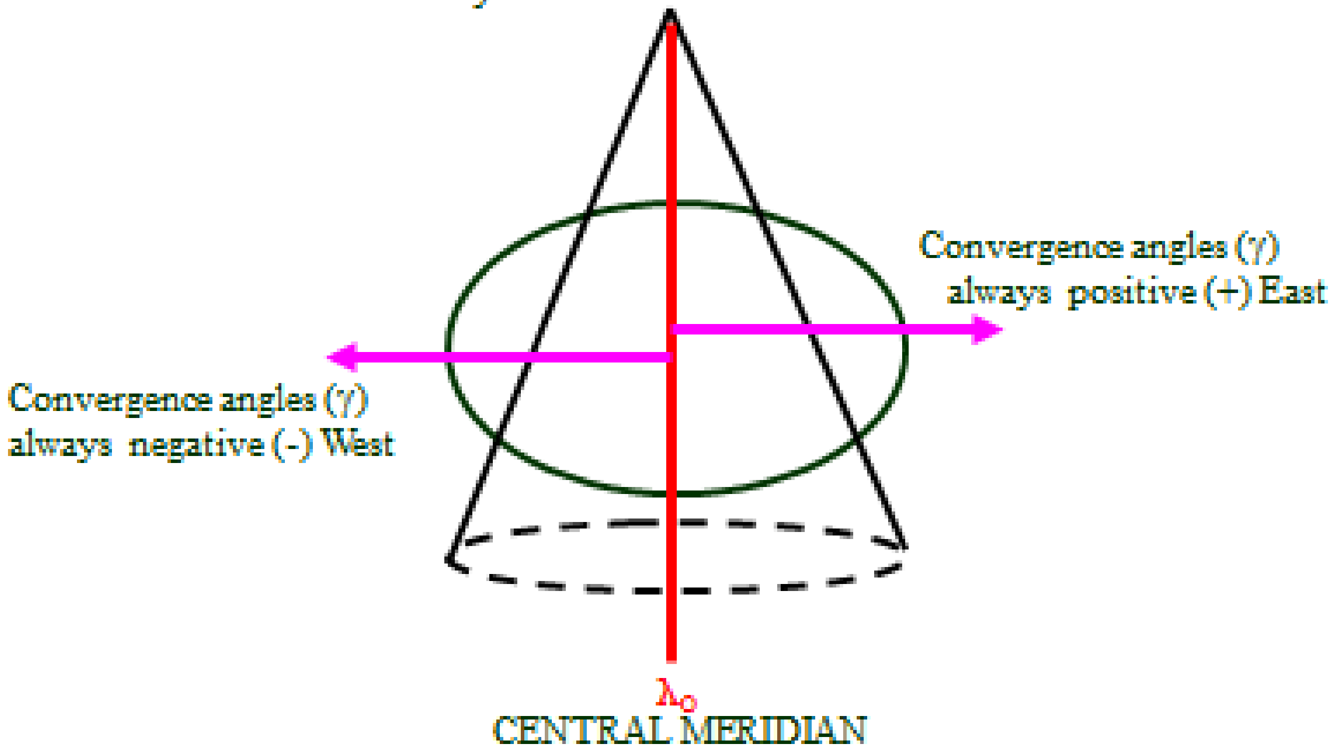


LAMBERT CONFORMAL CONIC WITH 2 STANDARD PARALLELS



CONVERGENCE ANGLE
(Mapping Angle)

The Convention of the Sign of the Convergence Angle is Always From Grid To Geodetic



STATE PLANE COORDINATE COMPUTATION

STRAUSS (pid KW0527)
N = 428,395.86 U.S. Survey Feet
E = 2,401,859.97 U.S. Survey Feet
Orthometric Height (H) = 642.24 Feet
Geoid Height (N) = - 113.32 Feet
Laplace Correction = - 2.6"
Grid Scale Factor (k) = 0.99995985
Meridian Convergence (γ) = + 1° 00' 39.8"
Observed Astro Azimuth (α_A) = 253° 26' 14.9"
Horizontal Distance (D) = 3,314.91 Feet

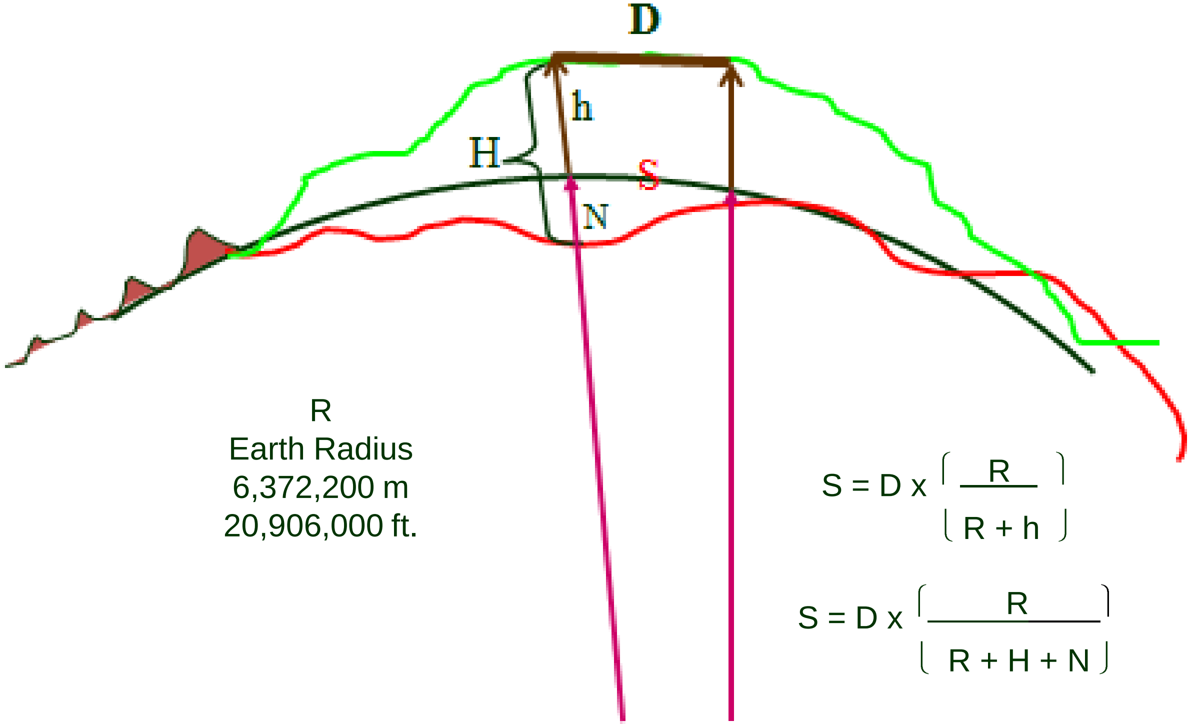
STATE PLANE COORDINATE COMPUTATION

$N_1 = N + (S_g \times \cos \alpha_g)$
$E_1 = E + (S_g \times \sin \alpha_g)$

Where:
N = Starting Northing Coordinate
E = Starting Easting Coordinates
S_g = Grid Distance
α_g = Grid Azimuth

MAHONING COUNTY ENGINEER'S OFFICE

REDUCTION TO ELLIPSOID



R
Earth Radius
6,372,200 m
20,906,000 ft.

$$S = D \times \left(\frac{R}{R + h} \right)$$

$$S = D \times \left(\frac{R}{R + H + N} \right)$$

REDUCTION TO ELLIPSOID
The correct method

$$R = \frac{N}{1 - e'^2 \cos^2 \phi \cos^2 \alpha}$$

WHERE:

$$N = \frac{a}{(1 - e'^2 \cos^2 \phi)^{1/2}}$$

$$e'^2 = (a^2 - b^2) / b^2$$

N = Radius of Curvature in Azimuth
a = Ellipsoid semi-major axis
b = Ellipsoid semi-minor axis
α= Azimuth of the line
ϕ = Latitude of the Station

REDUCTION TO ELLIPSOID
Ellipsoid Ht /Orthometric Ht

$S_{geodetic} = D \times [R / (R + h)]$
D = 3,314.91 ft. (Measured Horizontal Distance)
R = 20,906,000 ft. (Mean Radius of the Earth)
h = H + N (H = 642 ft., N = - 113 ft)
= 529 ft (Ellipsoid Height)

S = 3,314.91 [20,906,000 / 20,906,000 + 529]
S = 3,314.91 x 0.99997470
S = 3,314.83 ft.

$S_{geodetic}$ = 3,314.91 [20,906,000 / 20,906,000 + 642]
$S_{geodetic}$ = 3,314.91 x 0.99996929
$S_{geodetic}$ = 3,314.81 ft.

Difference = 0.02 ft. or ~ 1:166,000

REDUCTION TO ELLIPSOID
Mean Radius vs. Computed Earth Radius

$S_{geodetic} = D \times [R / (R + h)]$
D = 3,314.91 ft. (Measured Horizontal Distance)
R = 20,906,000 ft. (Mean Radius of the Earth)
R = 20,936,382 ft. (Computed Radius of the Earth)
h = 529

$S_{geodetic}$ = 3,314.91 ft. [20,906,000 / 20,906,000 + 529]
$S_{geodetic}$ = 3,314.91ft. x 0.99997470
$S_{geodetic}$ = 3,314.83 ft.

$S_{geodetic}$ = 3,314.91 [20,936,382 / 20,936,282 + 529]
$S_{geodetic}$ = 3,314.91 x 0.99997473
$S_{geodetic}$ = 3,314.83 ft.

Diff = 0.00 ft

GRID SCALE FACTOR (k) OF A POINT
GRID CONVERGENCE ANGLE (γ) OF A POINT

Easiest to obtain by using

NGS SPCs tool kit utility

or

CORPSCON

GRID SCALE FACTOR (k) OF A LINE

$$k_{12} = (k_1 + 4k_m + k_2) / 6$$

(m = mean of k_1 & k_2)

Typically the Average Value Works Fine

$$k_{12} = (k_1 + k_2) / 2$$

REDUCTION TO GRID

$$S_{grid} = S_{geodetic} * k \text{ (Grid Scale Factor)}$$

$$S_{grid} = 3{,}314.83 \times 0.99995985$$

$$S_{grid} = 3{,}314.70 \text{ ft.}$$

COMBINED FACTOR (CF)

CF = Ellipsoidal Reduction x Grid Scale Factor (k)

= 0. 0.99997470 x 0.99995985

= 0.99993455

$CF \times D = S_{grid}$

0.99993455 x 3,314.91 ft. = 3,314.69 ft.

GRID AZIMUTH COMPUTATION

$\alpha_{grid} = \alpha_{astro}$ + Laplace Correction – Convergence Angle (γ)

= 253° 26’ 14.9” (Observed Astro Azimuth)

- 2.6” (Laplace Correction)

= 253° 26’ 12.3” (Geodetic Azimuth)

- 1° 00’ 39.8” (Convergence Angle)

= 252° 25’ 32.5” (Grid Azimuth)

The convention of the sign of the convergence angle is always from Grid to Geodetic

STATE PLANE COORDINATE COMPUTATION

$N1 = N + (S_{grid} \times \cos \alpha_{grid})$
$E1 = E + (S_{grid} \times \sin \alpha_{grid})$

N1 = 428,395.86 + (3,314.70 x Cos 252° 25’ 32.5”)
= 428,395.86 + (3,314.70 x -0.301942400)
= 428,395.86 + (-1,000.85)
= 427,395.01 U.S. Survey Feet

E1 = 2,401,859.97 + (3,314.70 x Sin 252° 25’ 32.5”)
= 2,401,859.97 + (3,314.70 x -0.953326170)
= 2,401,859.97 + (-3,159.99)
= 2,398,699.98 U.S. Survey Feet

GROUND LEVEL COORDINATES
SURFACE LEVEL COORDINATES
PROJECT DATUM COORDINATES
LOW DISTORTION PROJECTIONS

"I WANT STATE PLANE COORDINATES RAISED TO GROUND LEVEL"

GROUND LEVEL COORDINATES ARE ***NOT*** STATE PLANE COORDINATES!!!!!

GROUND LEVEL COORDINATE NUISANCES

RAPID DISTORTIONS*

PROJECTS DIFFICULT TO TIE TOGETHER*

CONFUSION OF COORDINATE SYSTEMS

LACK OF DOCUMENTATION*

*Can be minimized with LDP

GROUND LEVEL COORDINATES
"IF YOU DO"

TRUNCATE COORDINATE VALUES

SUCH AS:

N = 404,648.89 ft. becomes 4,648.89

E = 26,341,246.75 ft. becomes 1,246.75

and

DOCUMENT!!!