Decoding the Mystery of Coordinates

NHLSA
TOWN MONUMENT LOCATION WORKSHOP
UNH – DURHAM, N.H.
8-11-2007

PART 1: THE DIFFERENT COORDINATE SYSTEMS

Decoding the Mystery of Coordinates

Objective of Presentation:

To introduce and discuss the common Surveying and Mapping Coordinate Systems

used to establish the position of monuments

PRESENTATION OUTLINE

- 4 SURFACES
- 3 HEIGHTS
- 2 DATUMS
- 4 COORDINATE SYSTEMS
- 3 DISTANCES
- 5 NORTHS

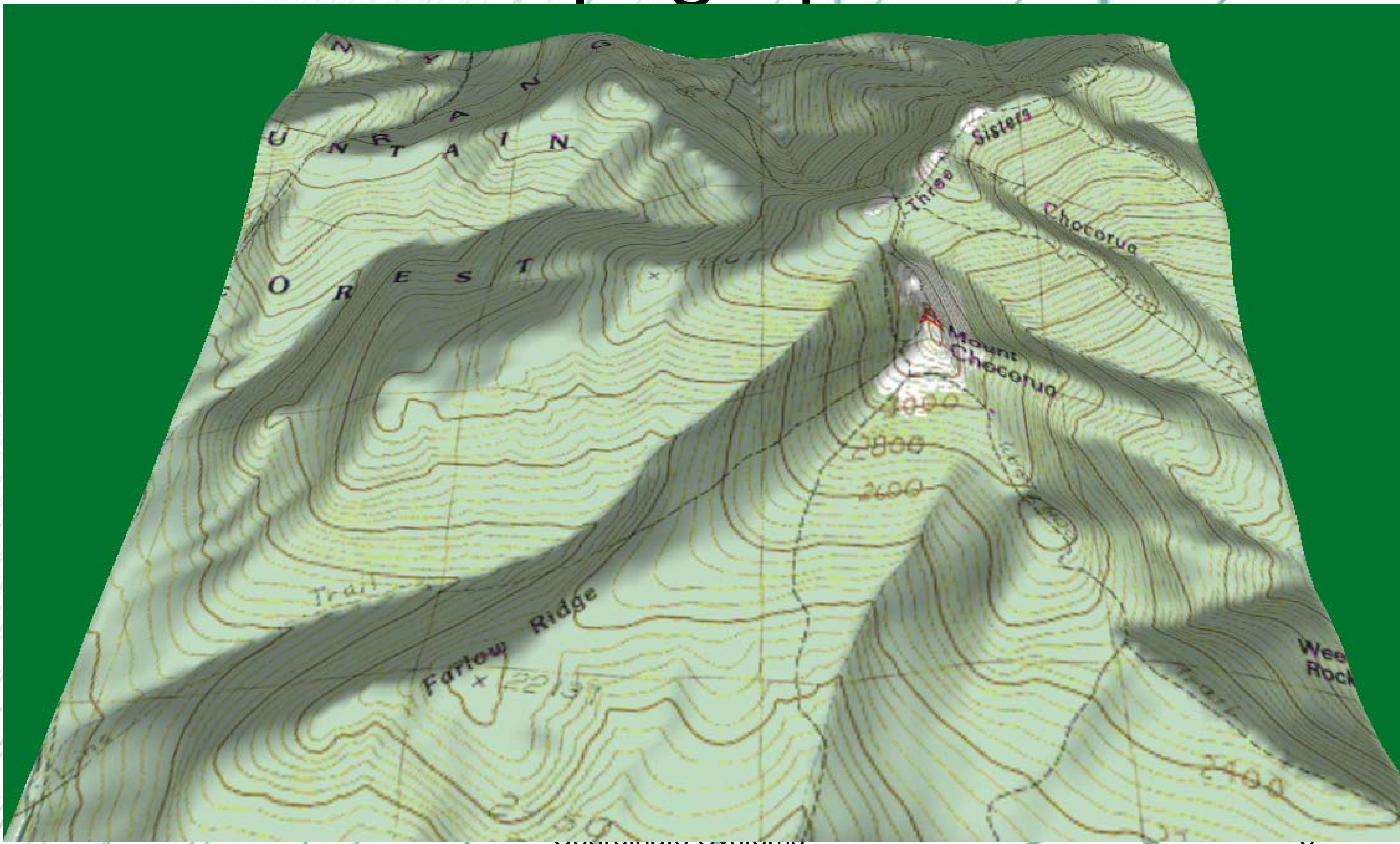
FOUR SURFACES

FOUR SURFACES

1- Earth - Topographic surface
2- Geoid - “Sea Level or “equipotential surf.
3- Ellipsoid - Mathematical surface
4- Grid - Projection, flat surface

1. Earth’s Topographic Surface

1. Earth's Topographic Surface



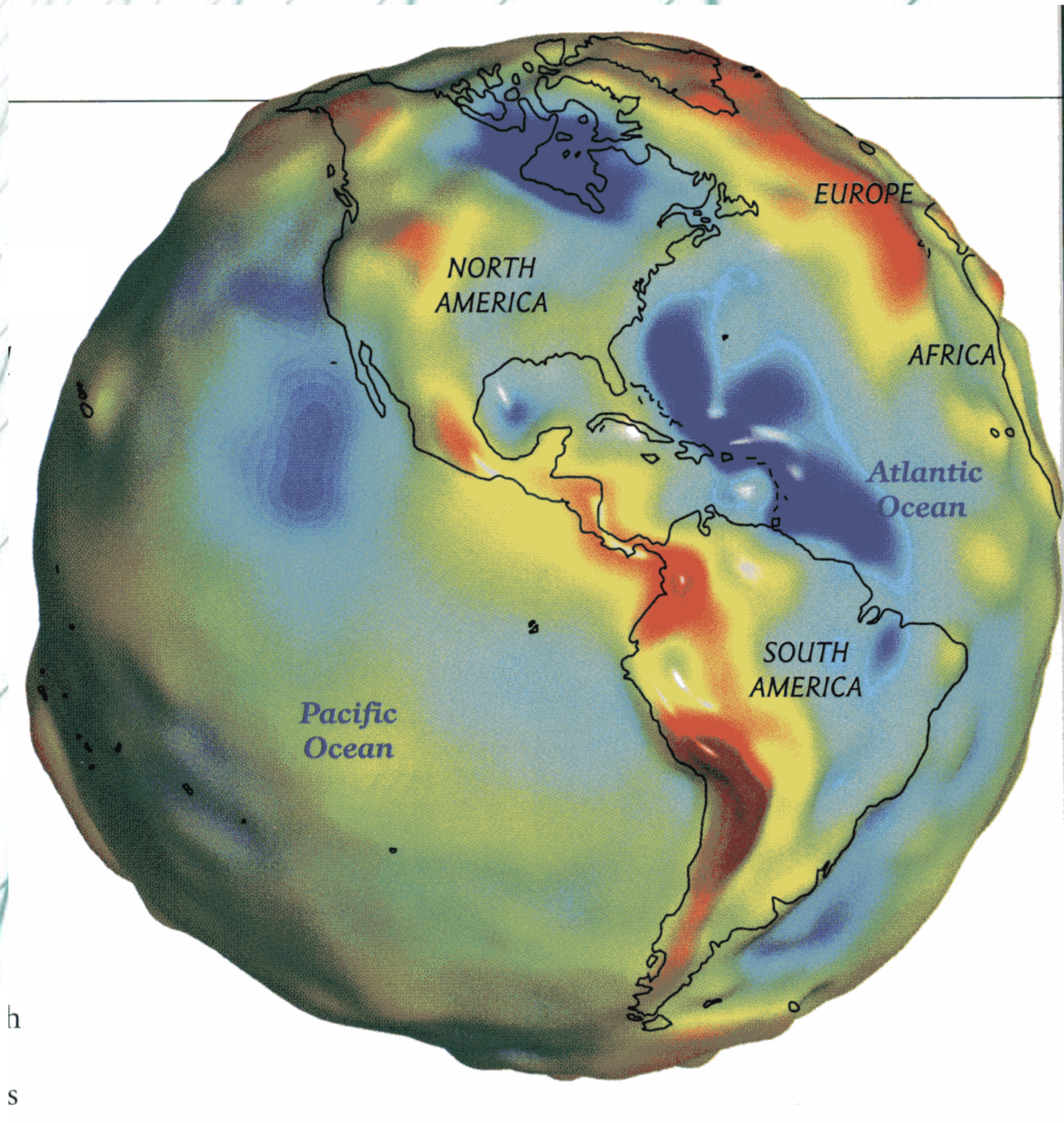
2. Earth's "Sea Level" Surface

THE GEOID:

Equipotential, or gravity surface

Current Model is Geoid 03

Gravity Recovery and Climate Experiment (GRACE)
Center for Space Research
Univ. of Texas



3. Earth's "Mathematical" Surface

THE ELLIPSOID:

World Geodetic System '84

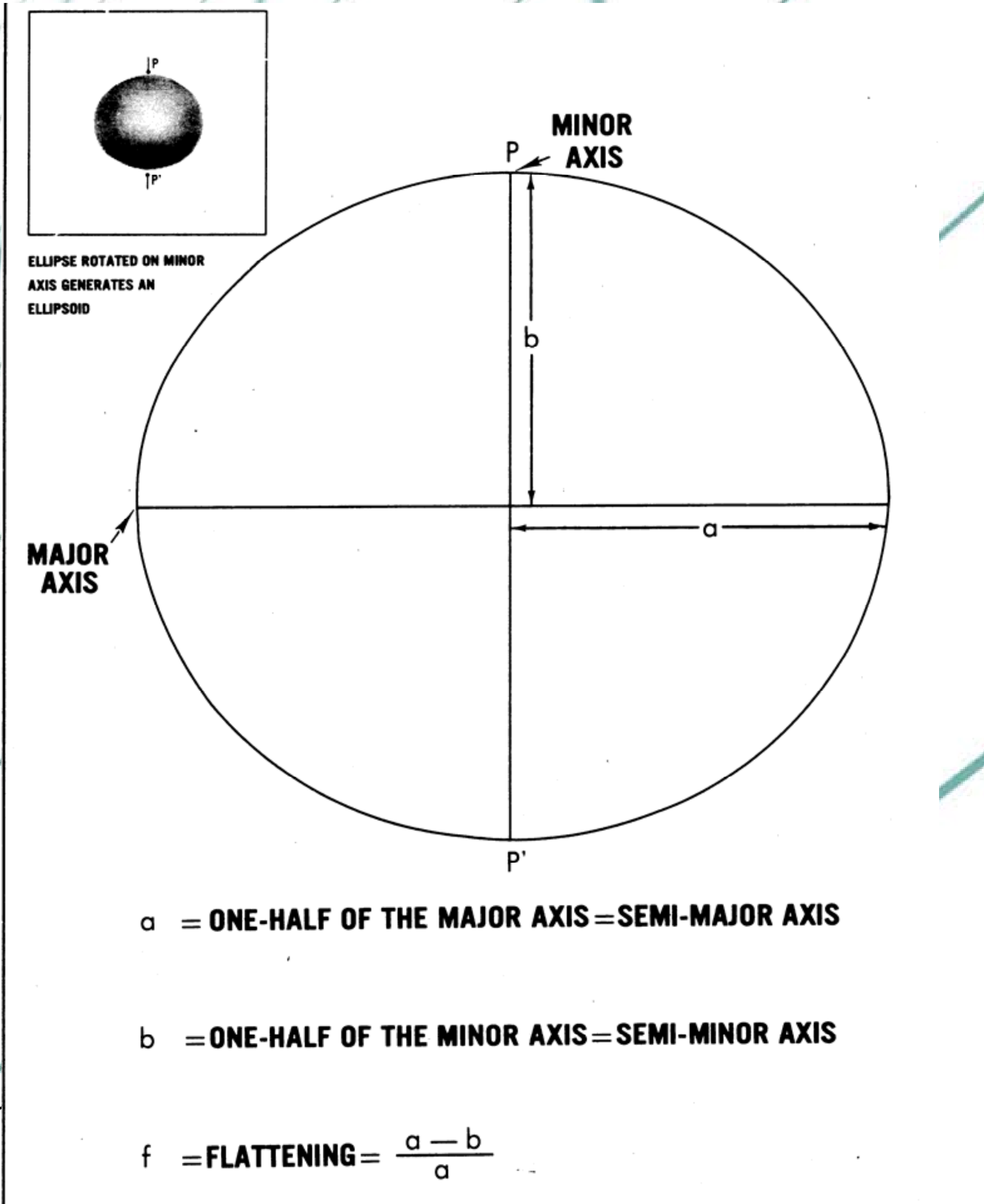
WGS '84

a = 6,378,137 meters

b = 6,356,752.3142 meters

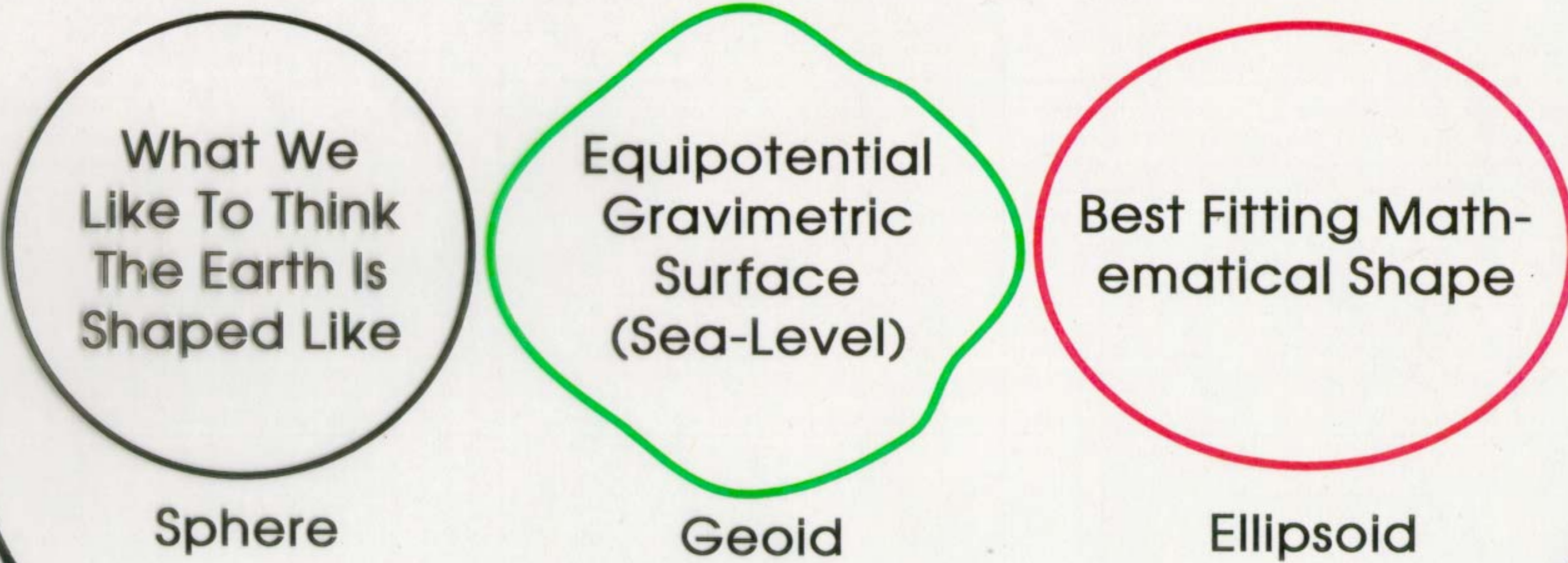
f = 1 / 298.25722

For a circle, flattening = 0



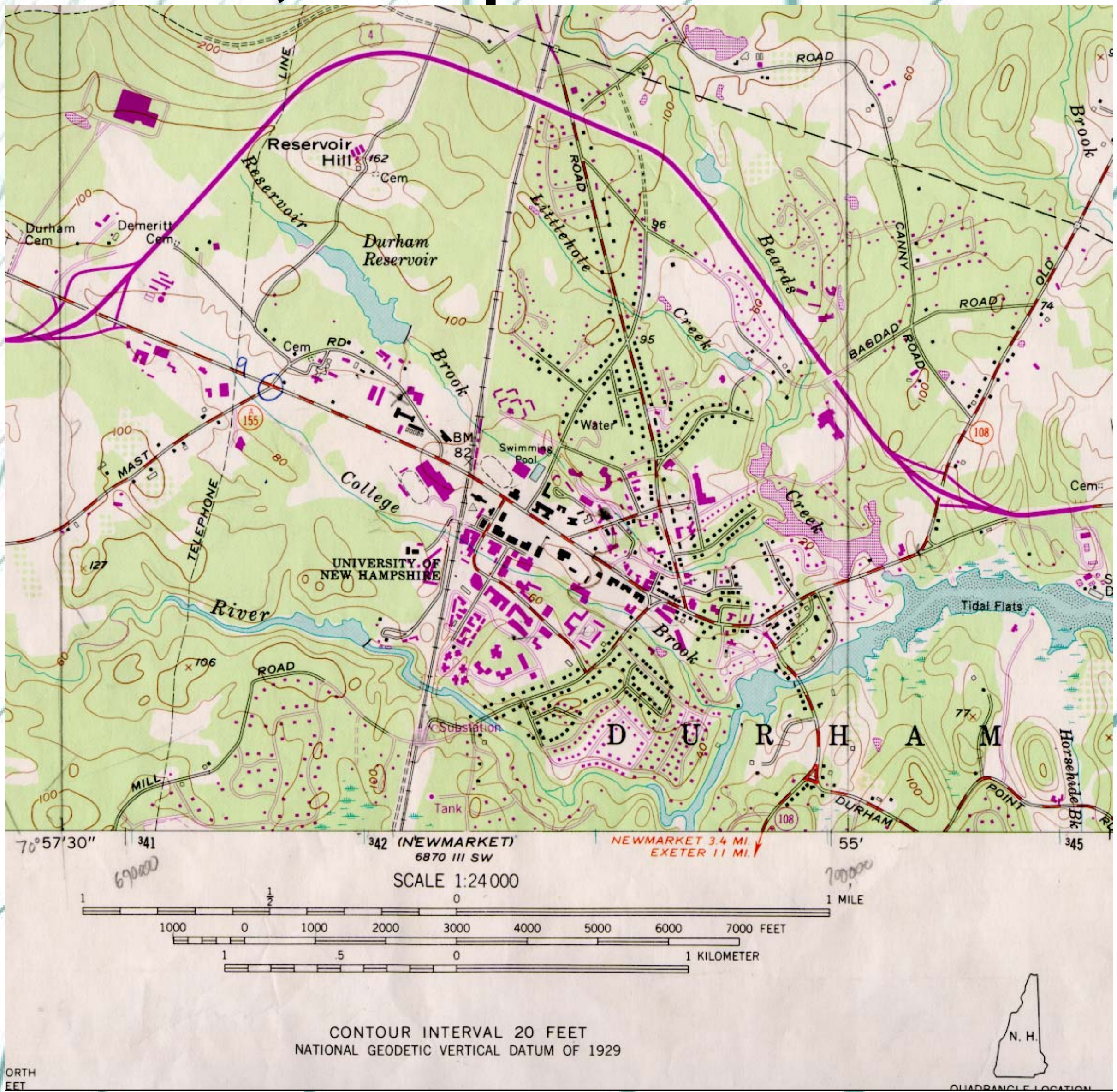
Geodetic Coordinate Systems

A Set Of Rules For Specifying How Coordinates Are To Be Assigned To Positions On The Surface Of The Earth. Defined BY X,Y,Z On An Ellipsoid



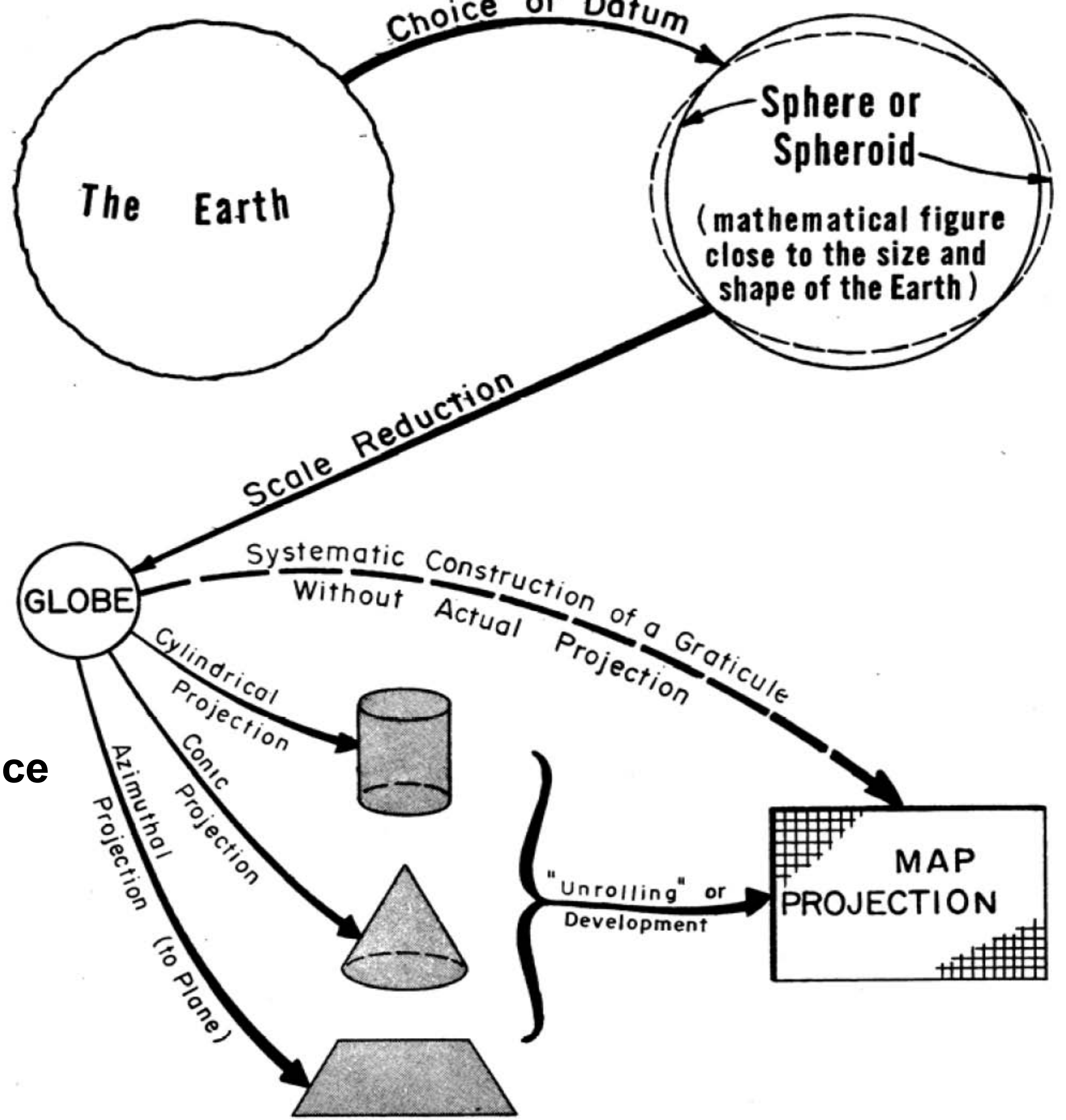
4. Earth's "Flat, Map" Surface

THE GRID



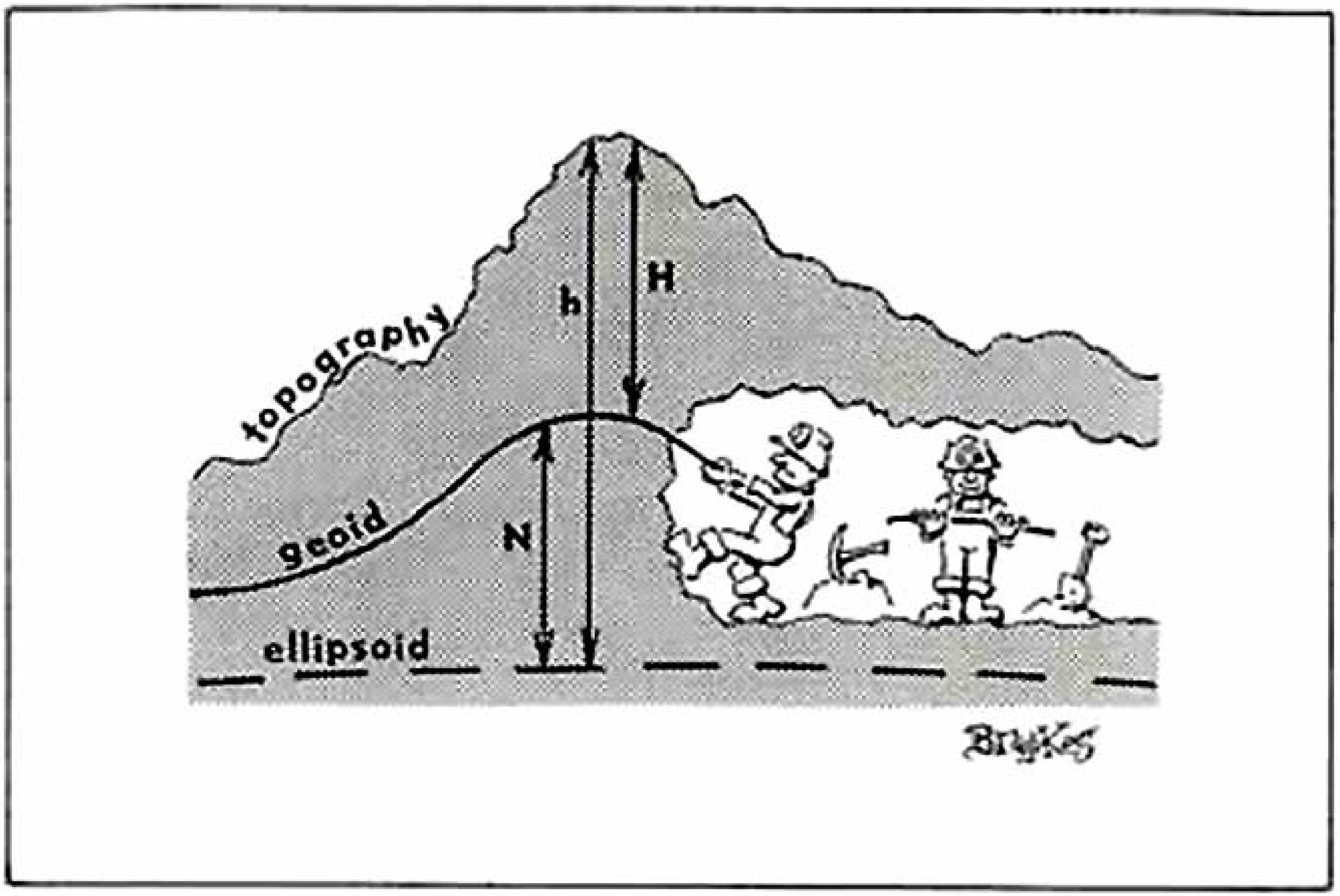
Creating The GRID:

1 A Mathematical Surface
2 Reduce the Scale
3 Project on a surface
4 Unroll the surface



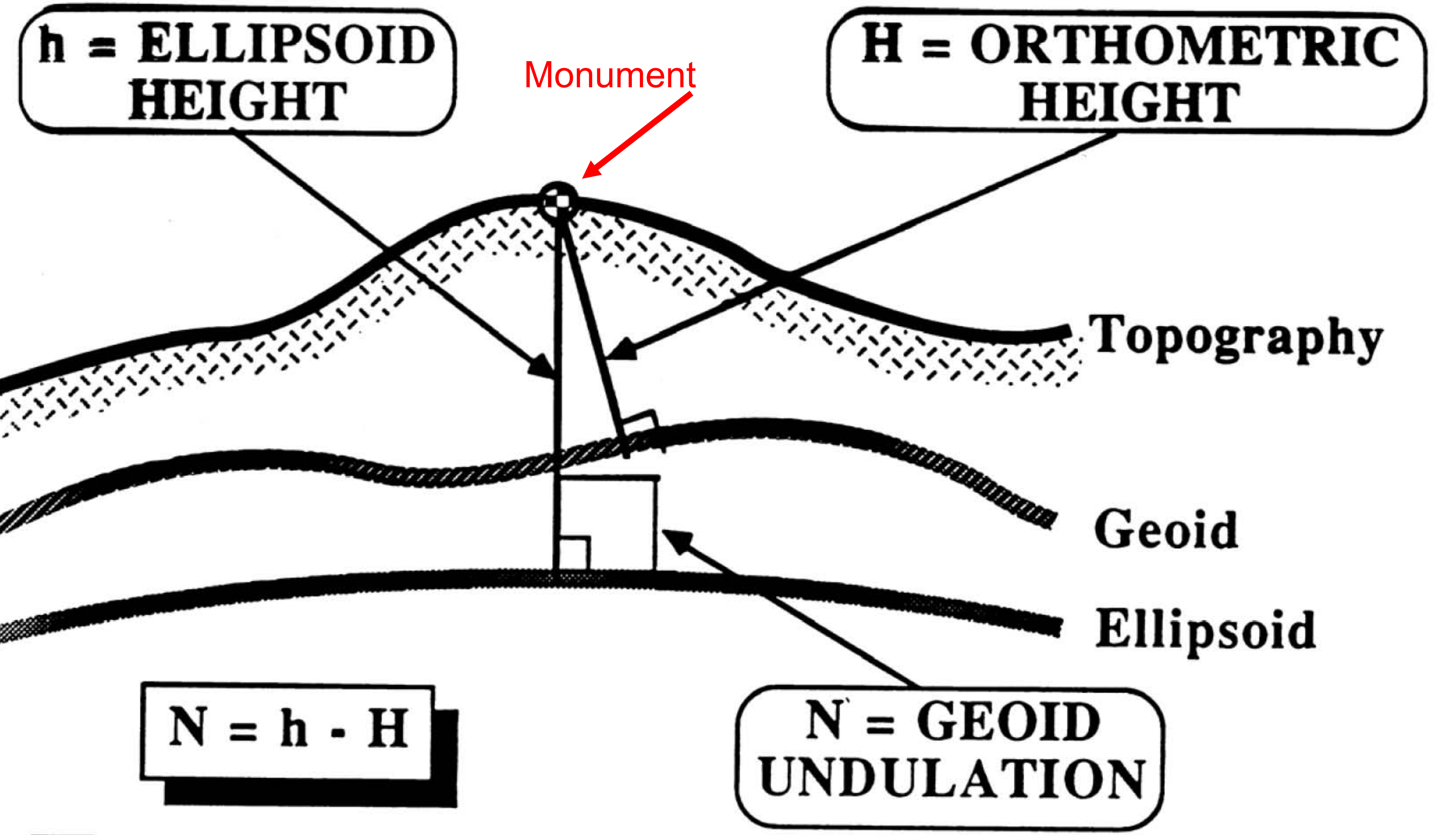
THREE “HEIGHTS”

In Search of the Geoid…



Courtesy of Natural Resources Canada www.geod.nrcan.gc.ca/index_e/geodesy_e/geoid03_e.html

THREE “HEIGHTS”



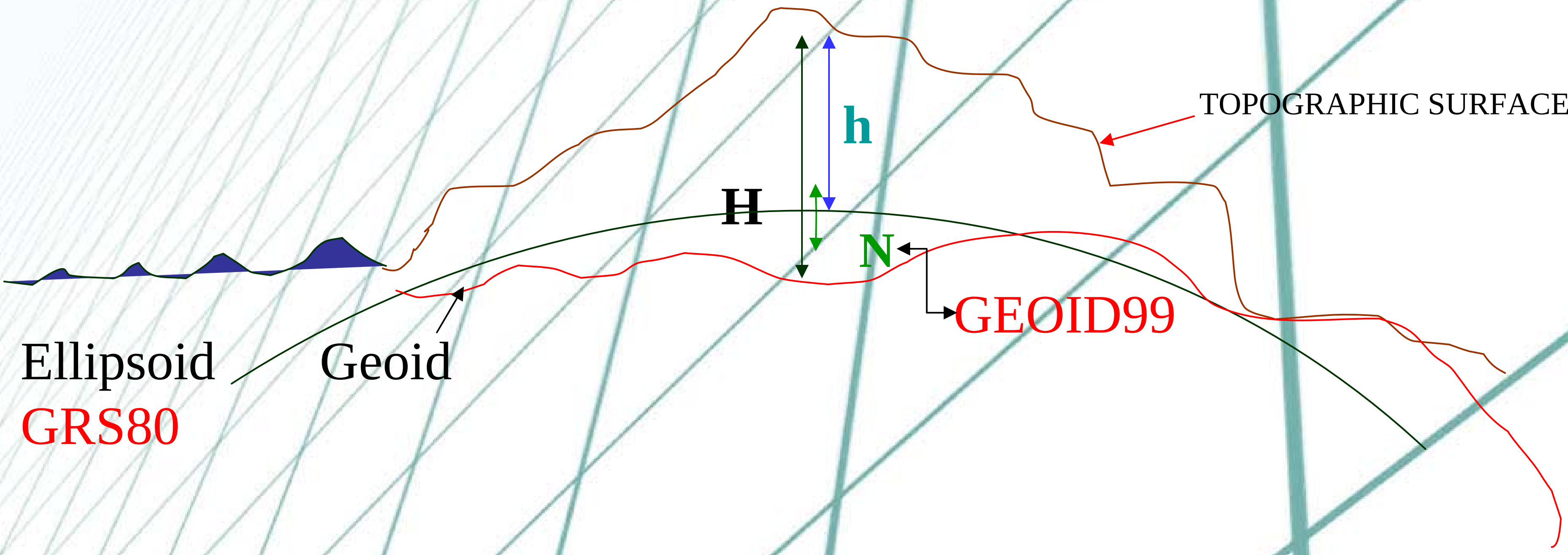
Ellipsoid, Geoid, and Orthometric Heights

H = Orthometric Height (NAVD 88)

h = Ellipsoidal Height (NAD 83)

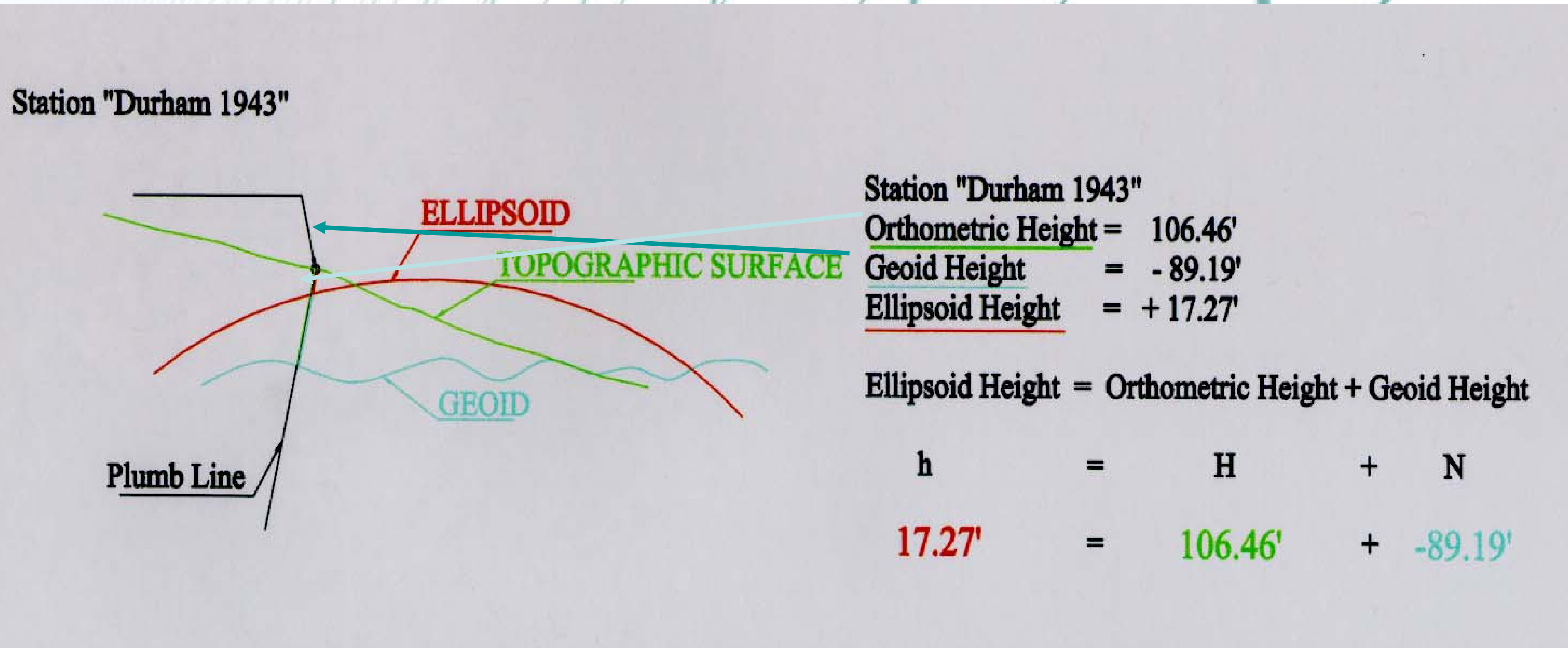
N = Geoid Height (GEOID 03)

h = H + N



Ellipsoid, Geoid, and Orthometric Heights

STATION “DURHAM 1943” : Has THREE “Heights”



TWO DATUMS

TWO DATUMS

A Datum:

Any numerical or geometrical quantity or set of such quantities which serve as a reference or base for calculation of other quantities. (GMS)

1. Horizontal Geodetic Datum: An Ellipsoid

2. Vertical Geodetic Datum: "Mean Sea Level" ≈ Geoid

What is a GEODETIC DATUM?

- Geodetic Datum
  - "A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth"*
  - "[above] together with the coordinate system and the set of all points and lines whose coordinates, lengths, and directions have been determined by measurement or calculation."*

*Definitions from the Geodetic Glossary, September 1986

Not To Be Confused With:

- Ellipsoid
  - "A closed surface, whose planar sections are either ellipsoids or circles."*
  - Mathematical figure which helps define a Reference Frame
  - Clarke 1866, GRS80
- Reference Frame
  - "A coordinate system associated with a physical system."*
  - NSRS, ITRF

*Definitions from the Geodetic Glossary, September 1986

1. Horizontal Control Datum

– “A Geodetic Datum specifying the coordinate system in which horizontal control points are located.”
– Defined by 8 Constants
  • 3 – specify the location of the origin of the coordinate system.
  • 3 – specify the orientation of the coordinate system.
  • 2 – specify the dimensions of the reference ellipsoid.
– NAD 27, NAD 83

*Definition from the Geodetic Glossary, September 1986

UNITED STATES ELLIPSOID DEFINITIONS

BESSEL 1841

a = 6,377,397.155 m 1/f = 299.1528128

f = (a-b)/a

CLARKE 1866

a = 6,378,206.4 m 1/f = 294.97869821

GEODETIC REFERENCE SYSTEM 1980 - (GRS 80)

a = 6,378,137 m 1/f = 298.257222101

WORLD GEODETIC SYSTEM 1984 - (WGS 84)

a = 6,378,137 m 1/f = 298.257223563

HORIZONTAL DATUMS

BESSEL 1841 -------------- LOCAL ASTRO DATUMS (1816-1879)

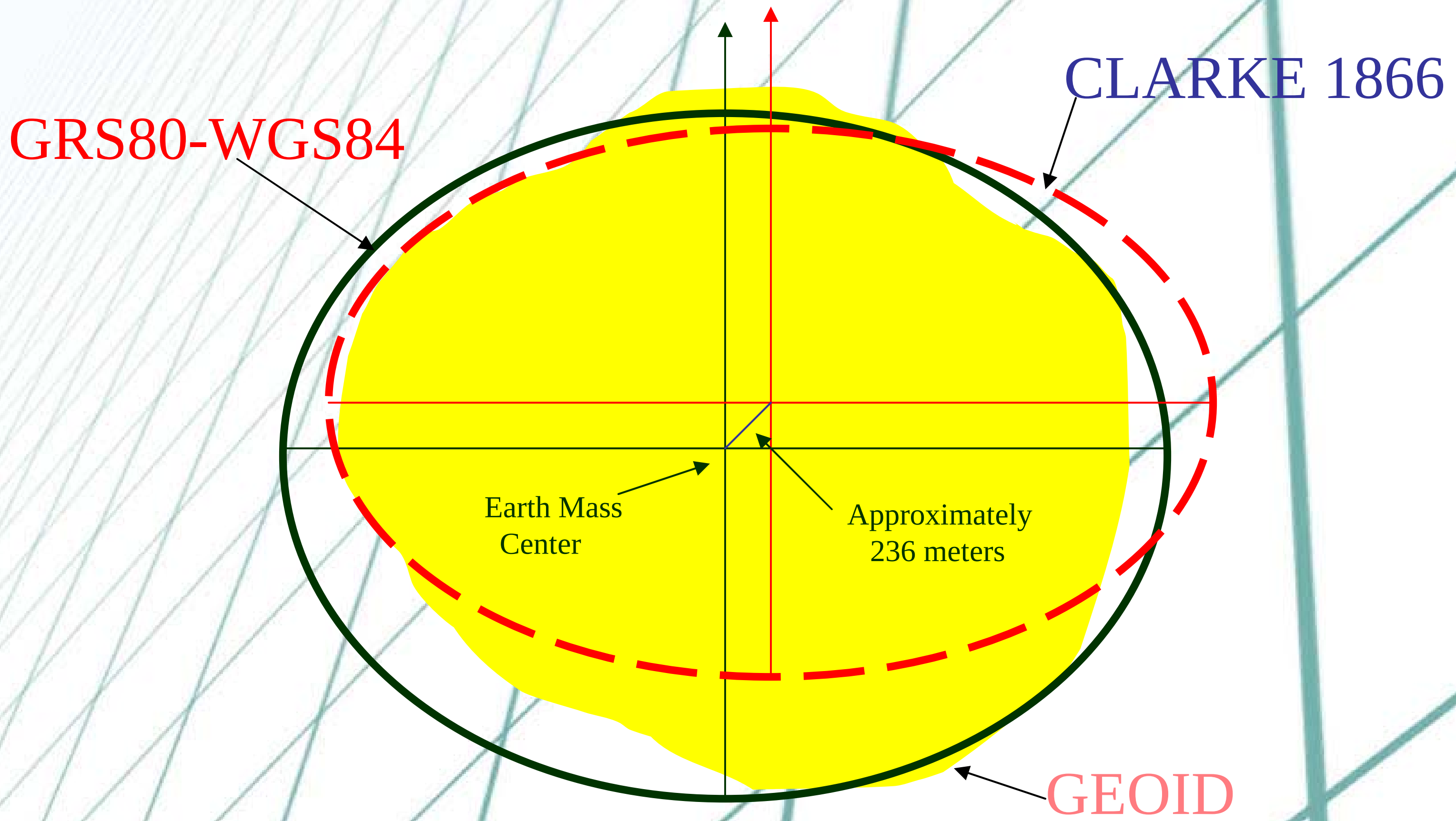
CLARKE 1866

- NEW ENGLAND DATUM (1879-1901)
- U.S. STANDARD DATUM (1901-1913)
- NORTH AMERICAN DATUM (1913-1927)
- NORTH AMERICAN DATUM OF 1927
- OLD HAWAIIAN DATUM
- PUERTO RICO DATUM
- ST. GEORGE ISLAND - ALASKA
- ST. LAWRENCE ISLAND - ALASKA
- ST. PAUL ISLAND - ALASKA
- AMERICAN SAMOA 1962
- GUAM 1963

GRS80 ----------- NORTH AMERICAN DATUM OF 1983

(As of June 14, 1989)

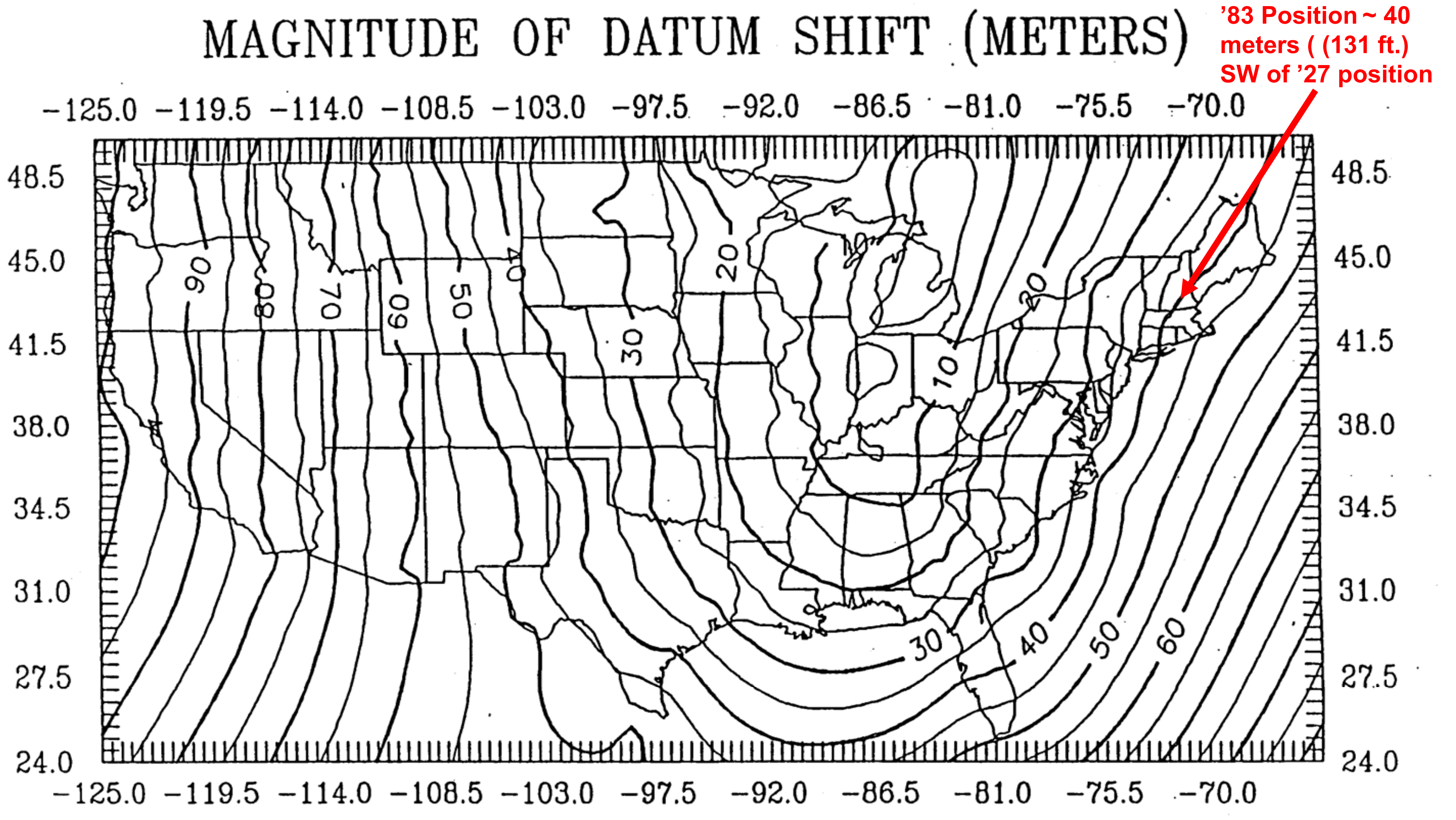
THE GEOID AND TWO ELLIPSOIDS



Comparison of Horizontal Datum Elements

	NAD 27	NAD 83
ELLIPSOID	CLARKE 1866 a = 6,378,206.4 m 1/f = 294.9786982	GRS80 a = 6,378,137. M 1/f = 298.257222101
DATUM POINT	Triangulation Station MEADES RANCH, KANSAS	NONE EARTH MASS CENTER
ADJUSTMENT	25k STATIONS Several Hundred Base Lines Several Hundred Astro Azimuths	250k STATIONS Appox. 30k EDMI Base Lines 5k Astro Azimuths Doppler Point Positions VLBI Vectors
BEST FITTING	North America	World-Wide

NAD 27 and NAD 83



2. Vertical Control Datum

A set of fundamental elevations to which other elevations are referred

Vertical Control Datum

- “A Geodetic Datum specifying the system in which vertical control points are located.”
- A set of fundamental elevations to which other elevations are referred
- NGVD 29, NAVD 88 – Orthometric, “Sea Level”
- Others – Cairo, Local Tidal

*Definitions from the Geodetic Glossary, September 1986

VERTICAL DATUMS

MEAN SEA LEVEL DATUM OF 1929

NATIONAL GEODETIC VERTICAL DATUM OF 1929

(As of July 2, 1973)

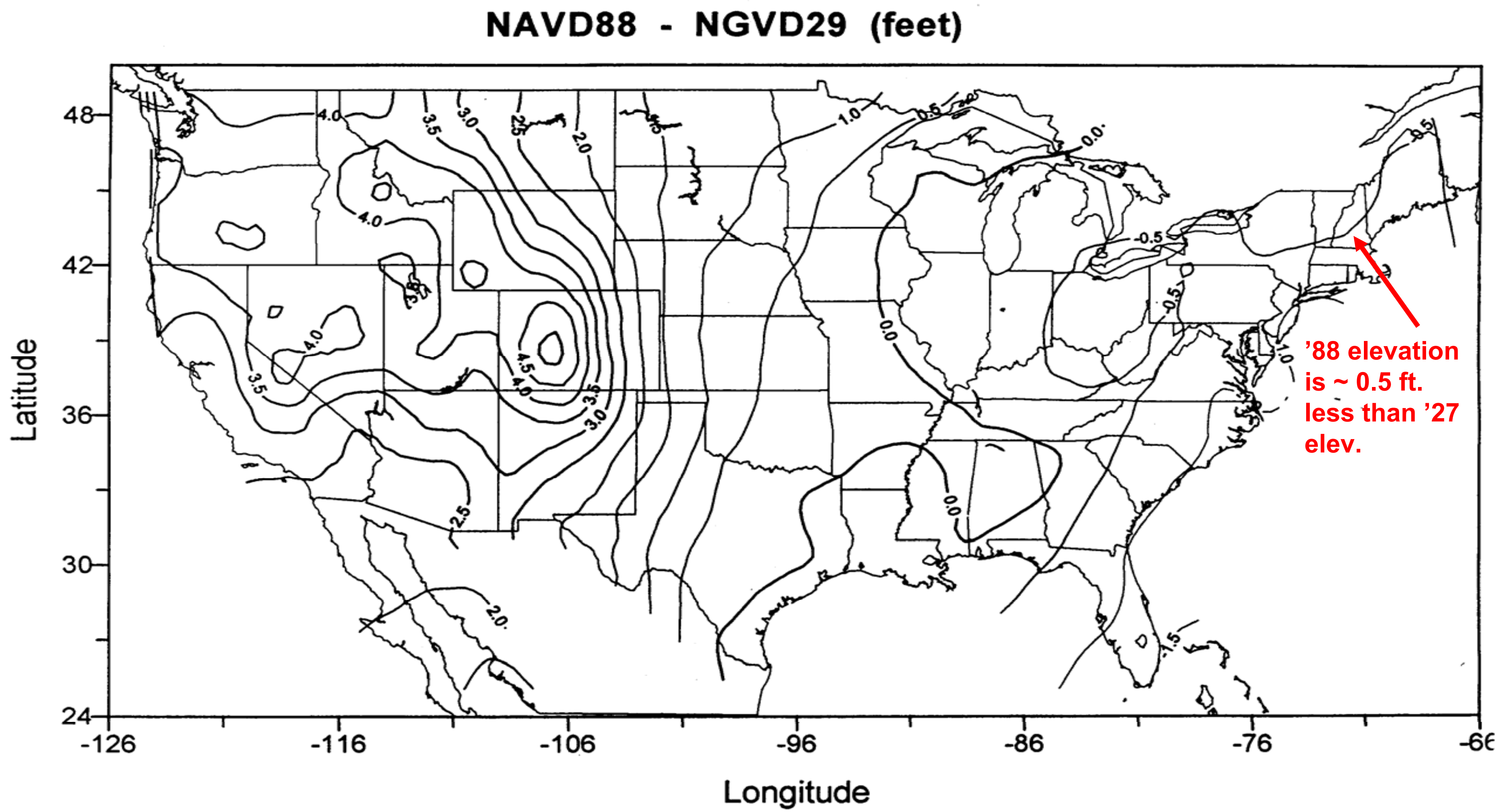
NORTH AMERICAN VERTICAL DATUM OF 1988

(As of June 24, 1993)

COMPARISON OF VERTICAL DATUM ELEMENTS

	NGVD 29	NAVD 88
DATUM DEFINITION	26 TIDE GAUGES IN THE U.S. & CANADA	FATHER'S POINT/RIMOUSKI QUEBEC, CANADA
BENCH MARKS	100,000	450,000
LEVELING (Km)	102,724	1,001,500
GEOID FITTING	Distorted to Fit MSL Gauges	Best Continental Model

NGVD 29 and NAVD 88



FOUR COORDINATE SYSTEMS

FOUR COORDINATE SYSTEMS (3D)

1. GEOCENTRIC COORDINATES:

   X,Y,Z

2. GEODETIC COORDINATES

   Φ,λ,h

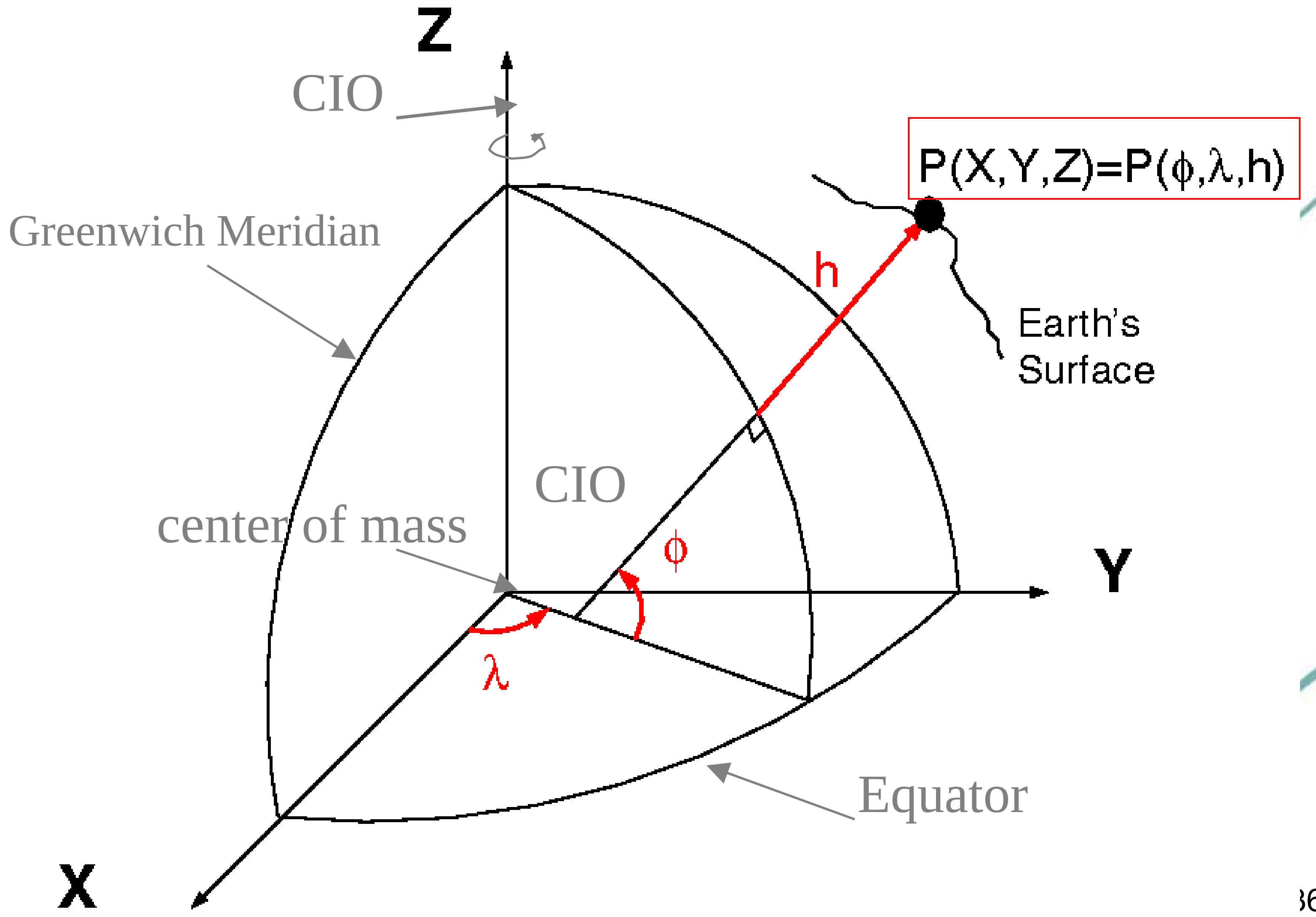
3. CARTESIAN (PLANE) COORDINATES

   N,E,H (State Plane Coordinates., UTM coord.)

4. ASSUMED COORDINATES

   Y, X, Elevation

1. Geocentric Coordinates
Conventional Terrestrial System (CTS)



1. Geocentric Coordinates (Ctd.)

- Conventional Terrestrial Reference System (CTRS) also called
- Earth Centered Earth Fixed System (ECEF) requires a
- Reference Frame (set of reference station coordinates) one is
- International Terrestrial Reference Frame of WGS 1984

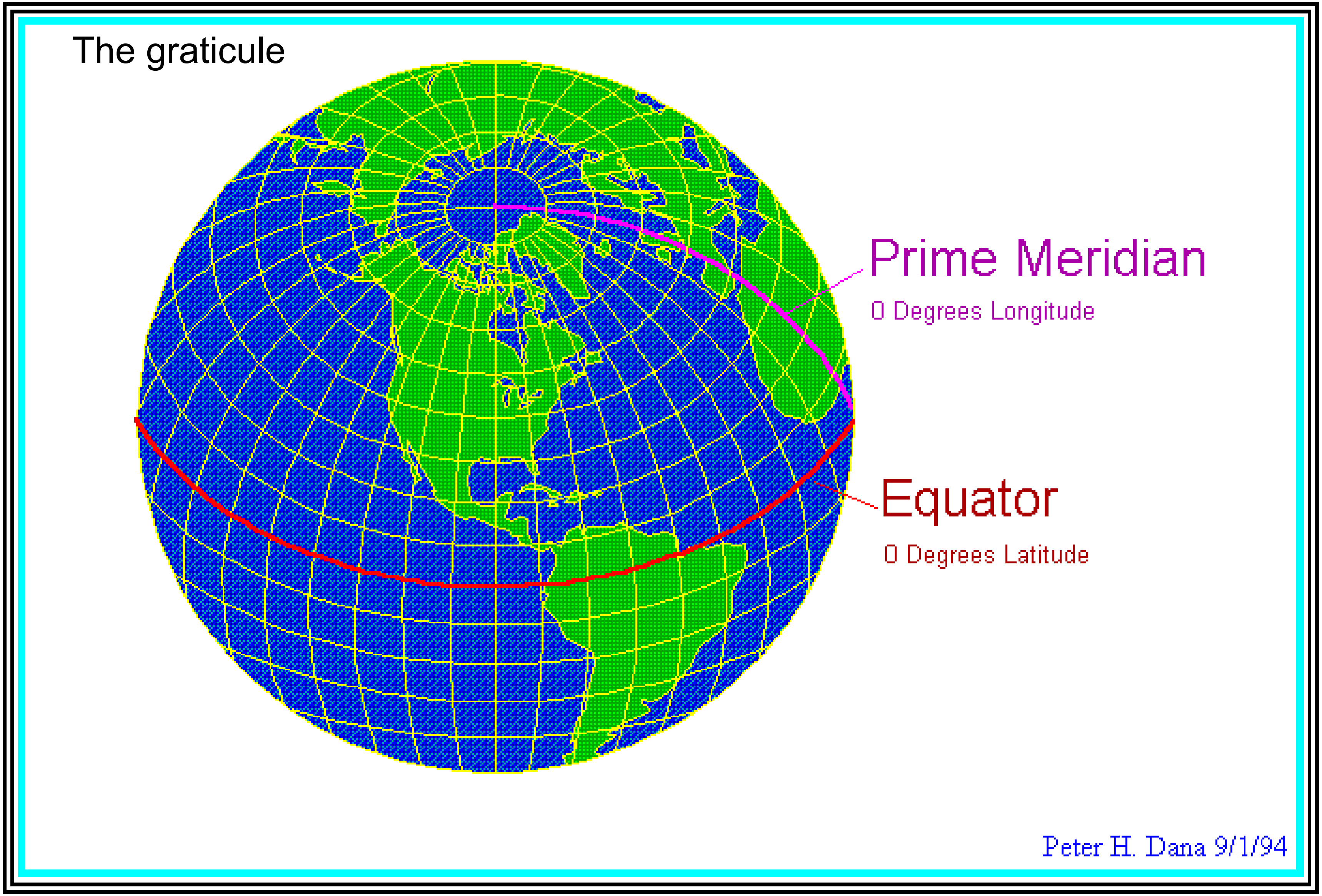
1. Geocentric Coordinates (Ctd.)

- ITRF
  - Origin at center of mass of the earth
  - Z axis passes through the International Reference Pole (IRP) as defined by the International Earth Rotation Service (IERS)
  - X axis through point of zero Longitude (on plane of conventional equator)
  - Y Axis formed by a right-handed coordinate frame and passes close to the Greenwich Meridian

2. Geodetic Coordinates

- LATITUDE: ϕ (PHI)
- LONGITUDE: λ (LAMBDA)
- Ellipsoid Height: h

2. Geodetic Coordinates

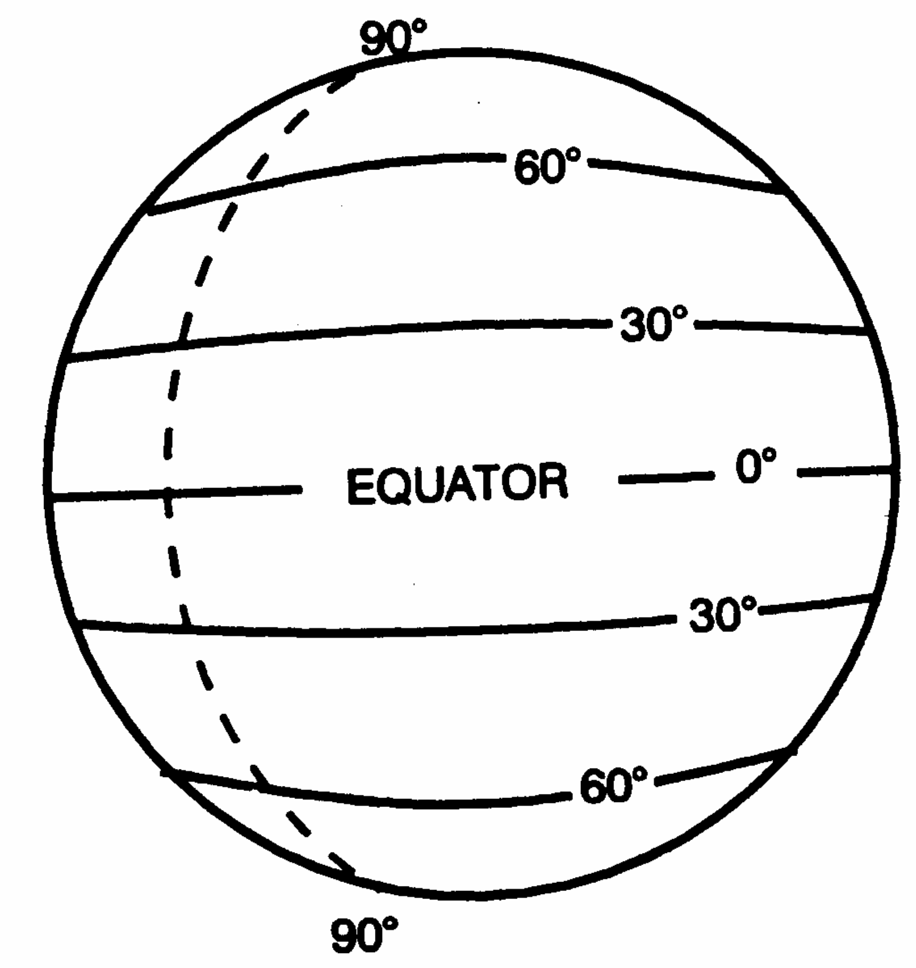


2. Geodetic Coordinates

- LATITUDE: ϕ

The north-south position on the Globe

"A Parallel"

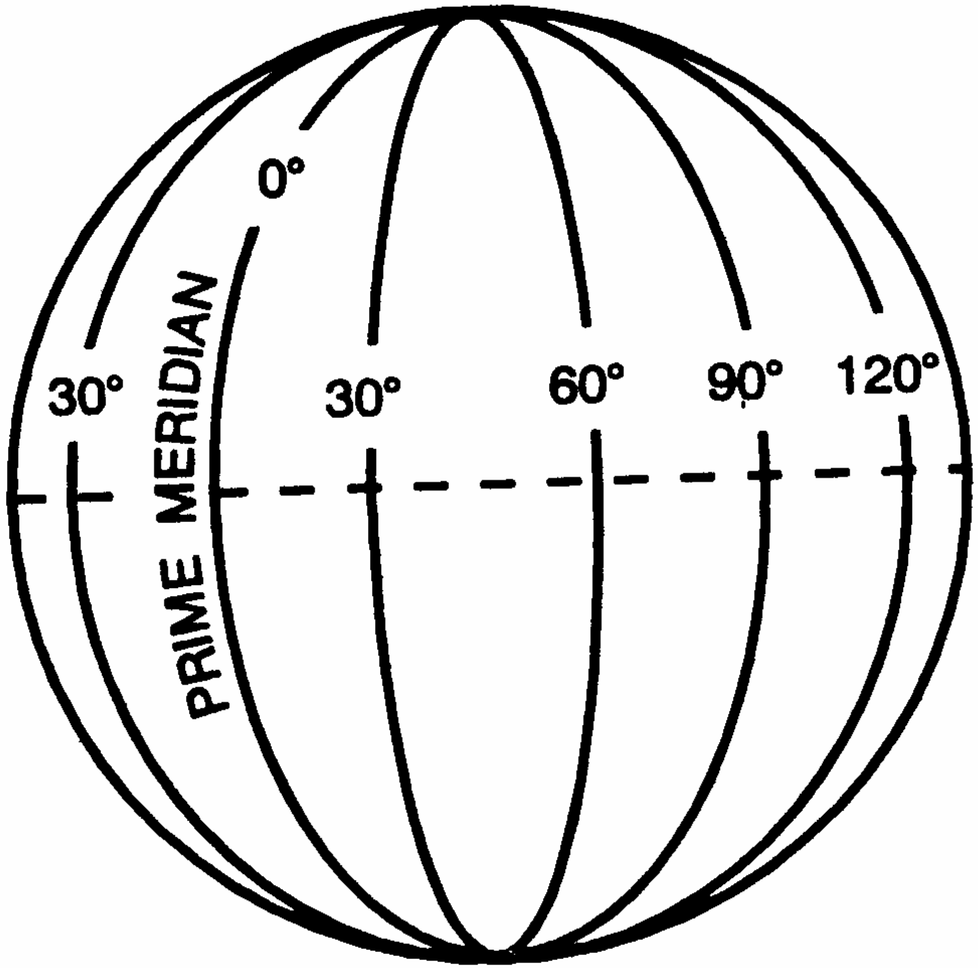


2. Geodetic Coordinates

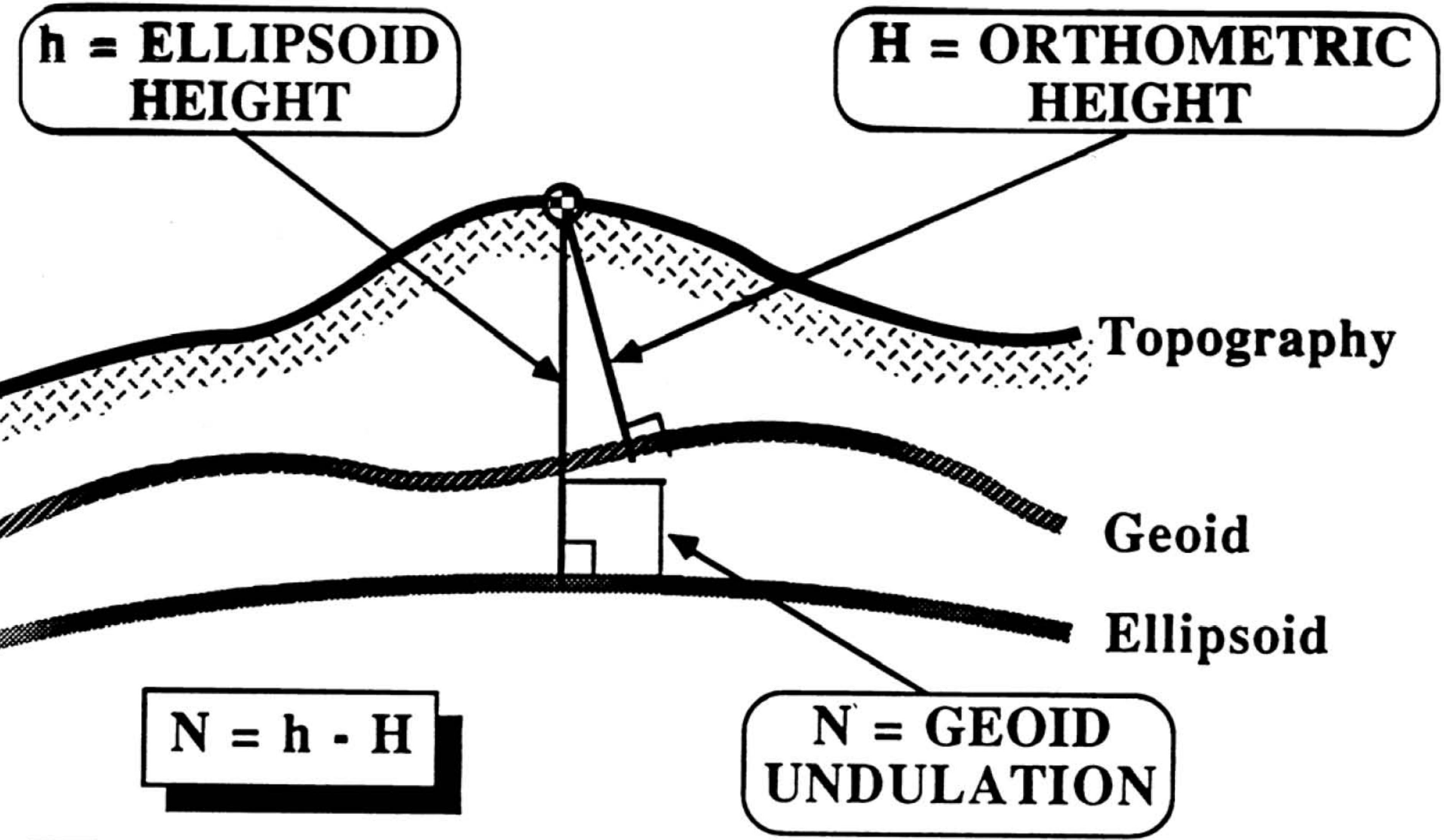
- LONGITUDE: λ

The east - west position on the Globe

"A Meridian"



Remember Ellipsoid Height (h)?



3. CARTESIAN (PLANE) COORDINATES

- **STATE PLANE COORDINATES** (SPC):
  - Transverse Mercator States
  - Lambert Conformal States
  - 2 Issues
    - Convergence/Mapping Angle
    - Ground → Geodetic → Grid Distances
- **UNIVERSAL TRANSVERSE MERCATOR** COORDINATES (UTM):
  - US National Grid (USNG)

3. CARTESIAN COORDINATES

- NORTHING: N (Y)
- EASTING: E (X)
- Orthometric Height: H (elevation)

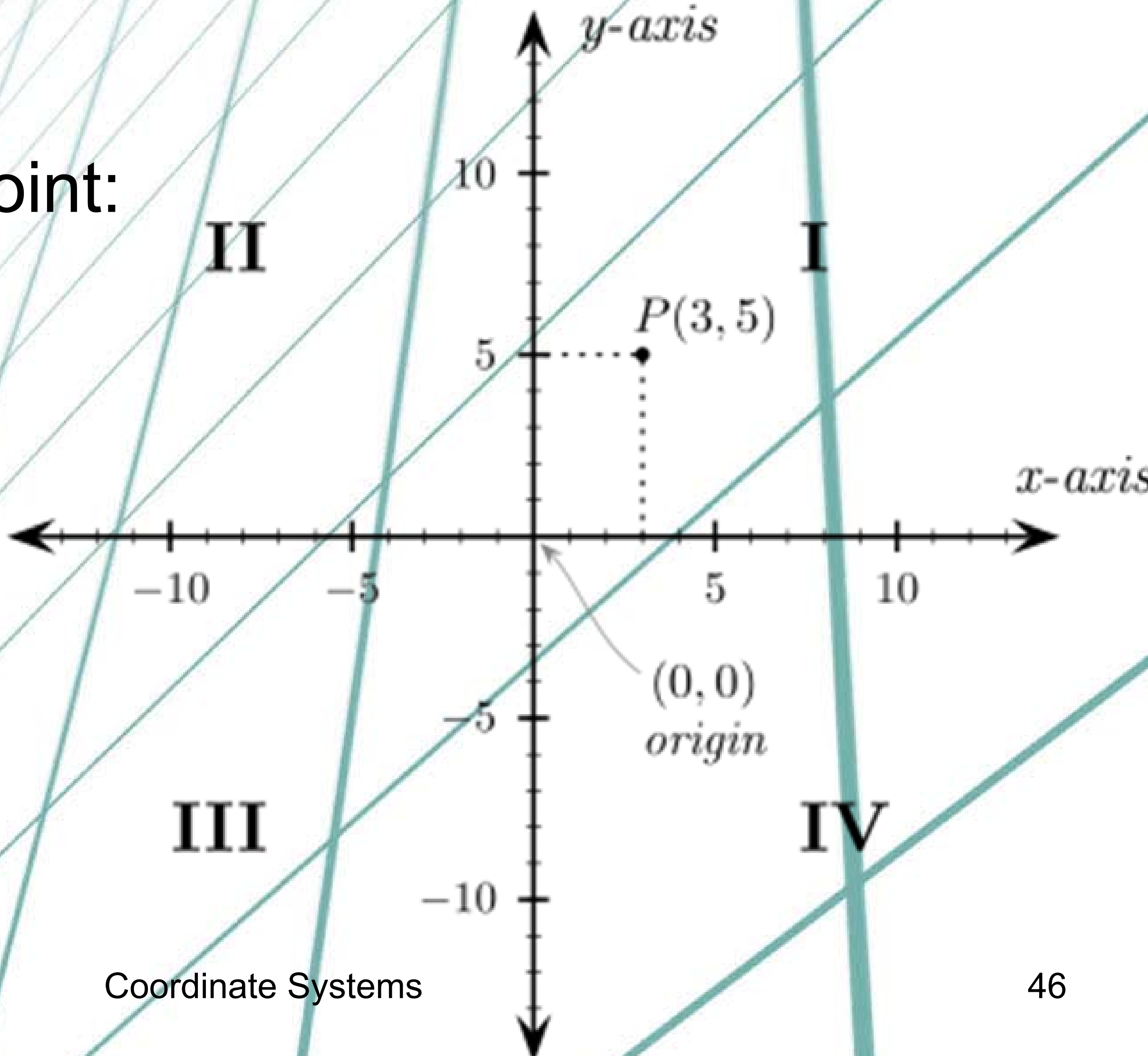
3. CARTESIAN COORDINATES

Two dimensional
coordinates of a point:

X,Y

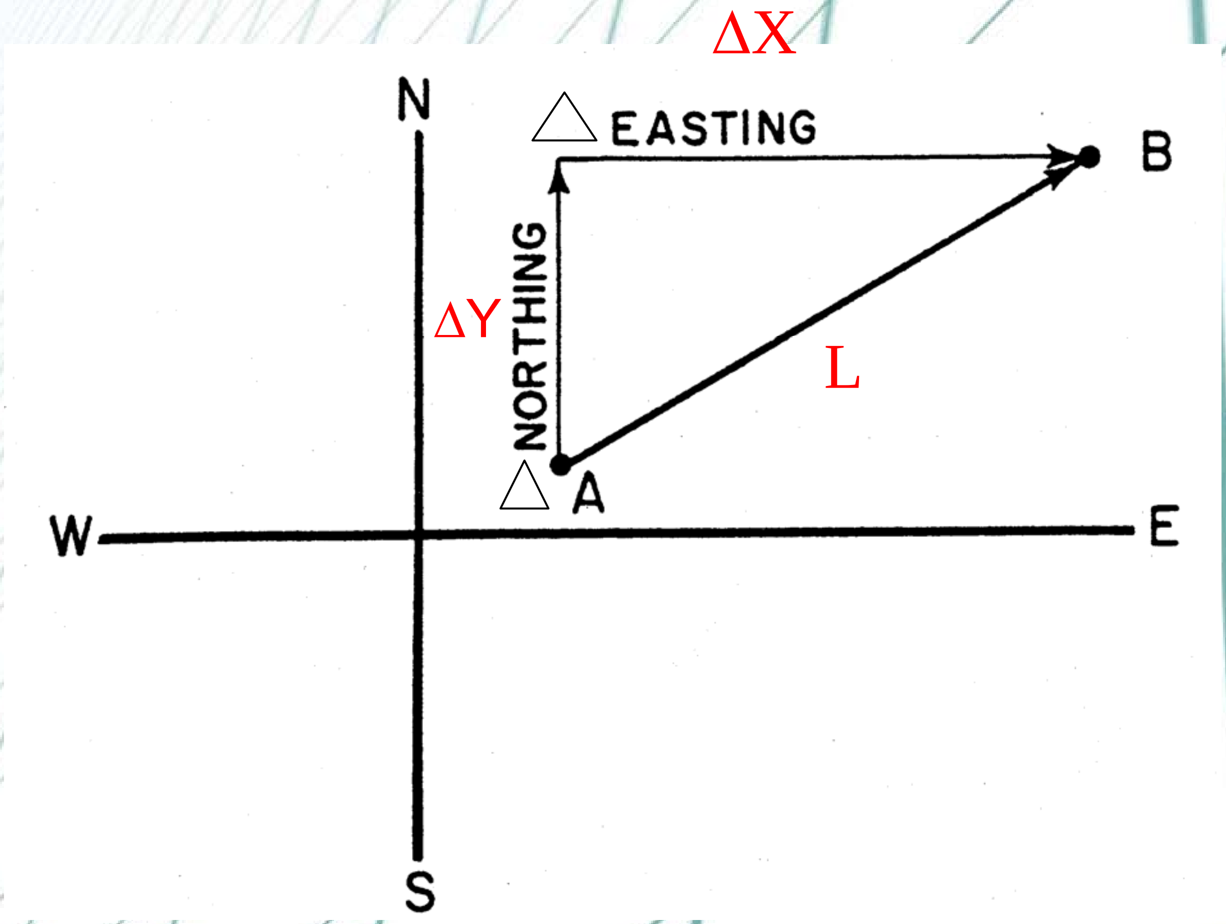
or

N,E (Y,X)



From Wikipedia

3. CARTESIAN COORDINATES



3. CARTESIAN COORDINATES

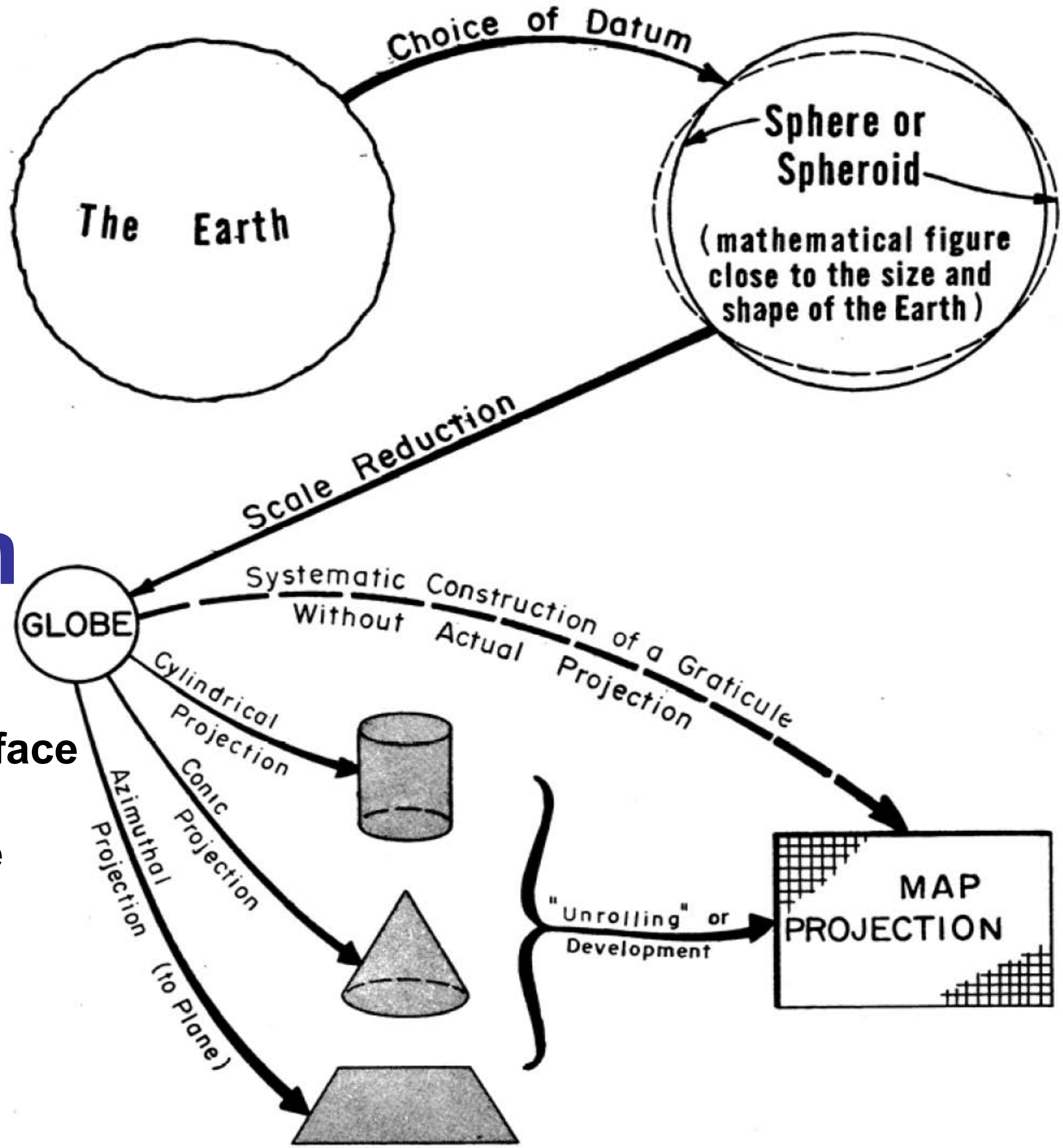
To obtain Cartesian (plane) coordinates from a round surface.

We must “Flatten” the earth by

MAP PROJECTION

The four steps in Map Projection

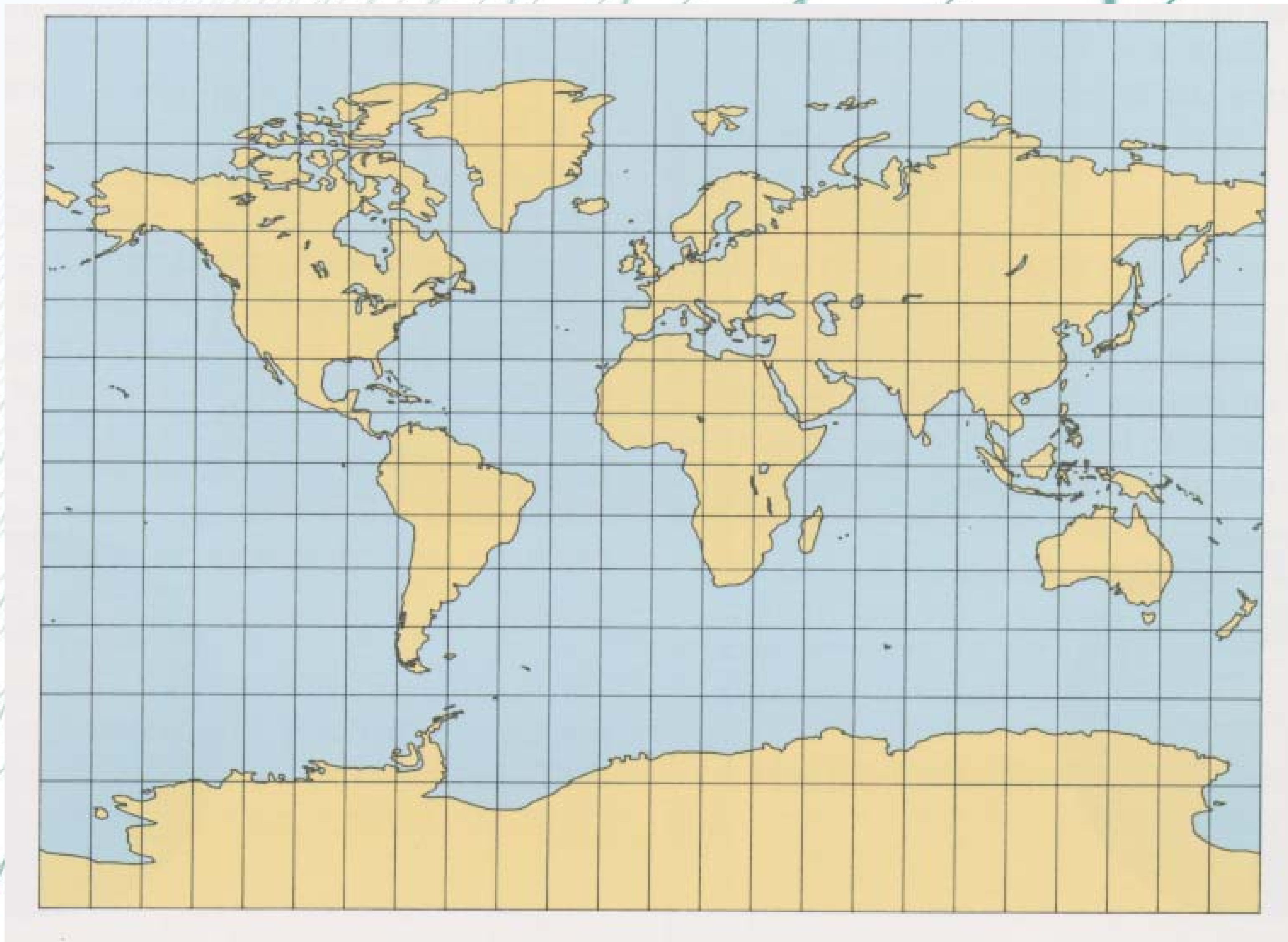
1 A Mathematical Surface
2 Reduce the Scale
3 Project on a surface
4 Unroll the surface



MAP PROJECTIONS:
CONIC AND CYLINDRICAL

Globe

Flat Map Projection (Mercator)



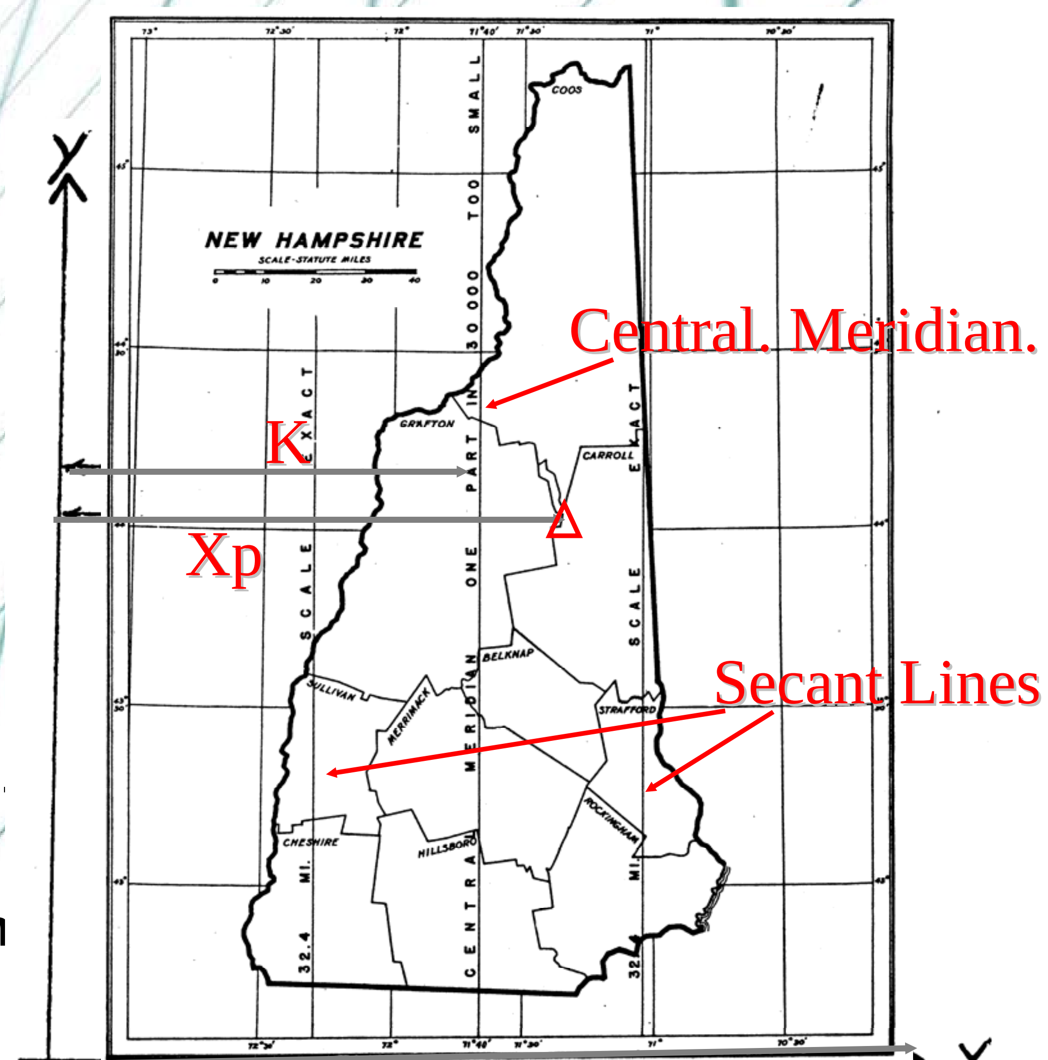
3a. The Transverse Mercator Projection System

New Hampshire State Plane Coordinates Based on the T M System:

Offset of the Central Meridian:

NAD27 System K = 500,000 ft.

NAD83 System K = 300,000 m



The transverse Mercator projection

3a. The N.H. State Plane Coordinate System

CENTRAL MERIDIAN IN N.H.

$\lambda = 71° 40'$

BETWEEN SECANT LINES:

Scale Factor less than 1

OUTSIDE SECANT LINES:

Scale Factor greater than1

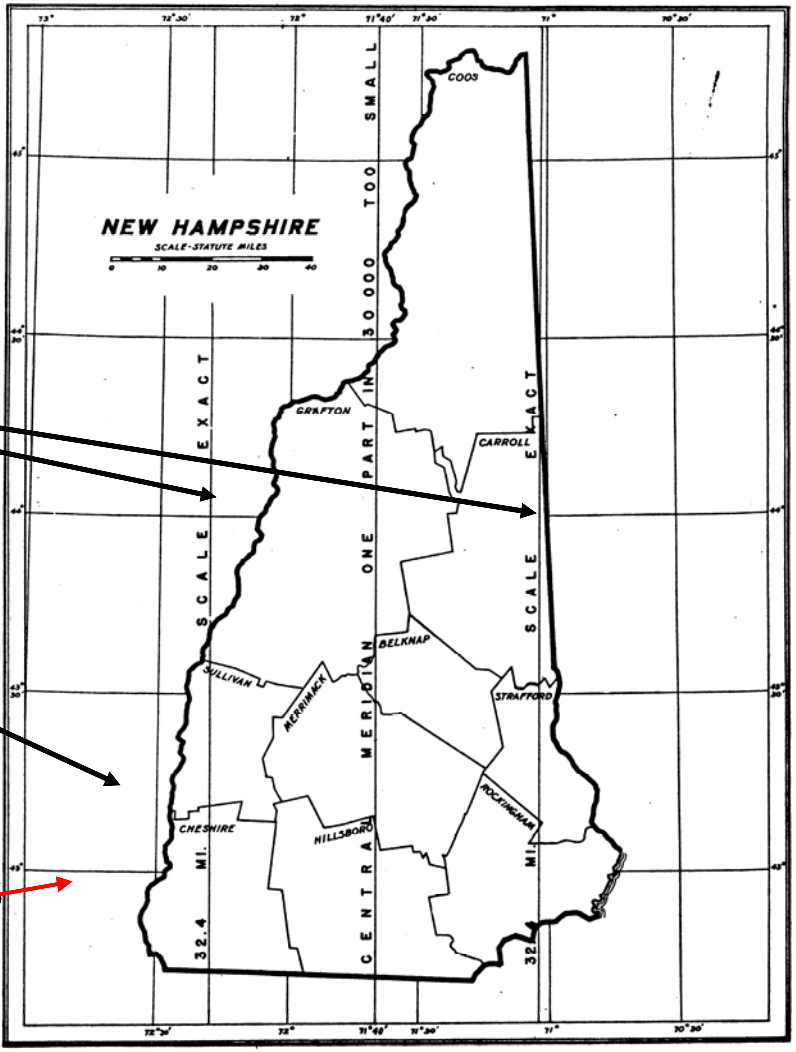
Scale factor constant in N -S direction

Scale Factor varies in the E - W direction

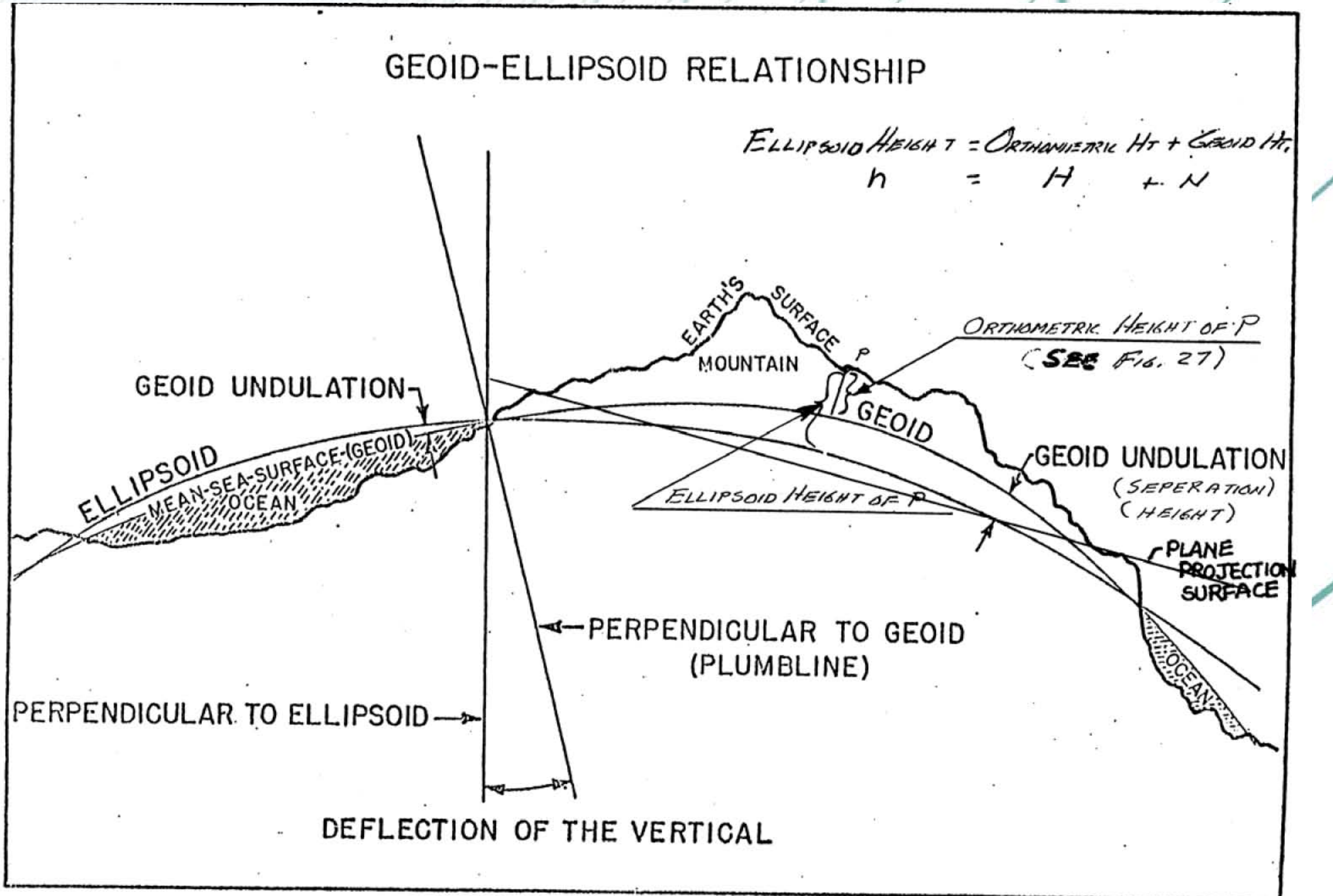
ALSO NOTICE:CONVERGENCE OF MERIDIANS

CURVATURE OF PARALLELS

Coordinate System



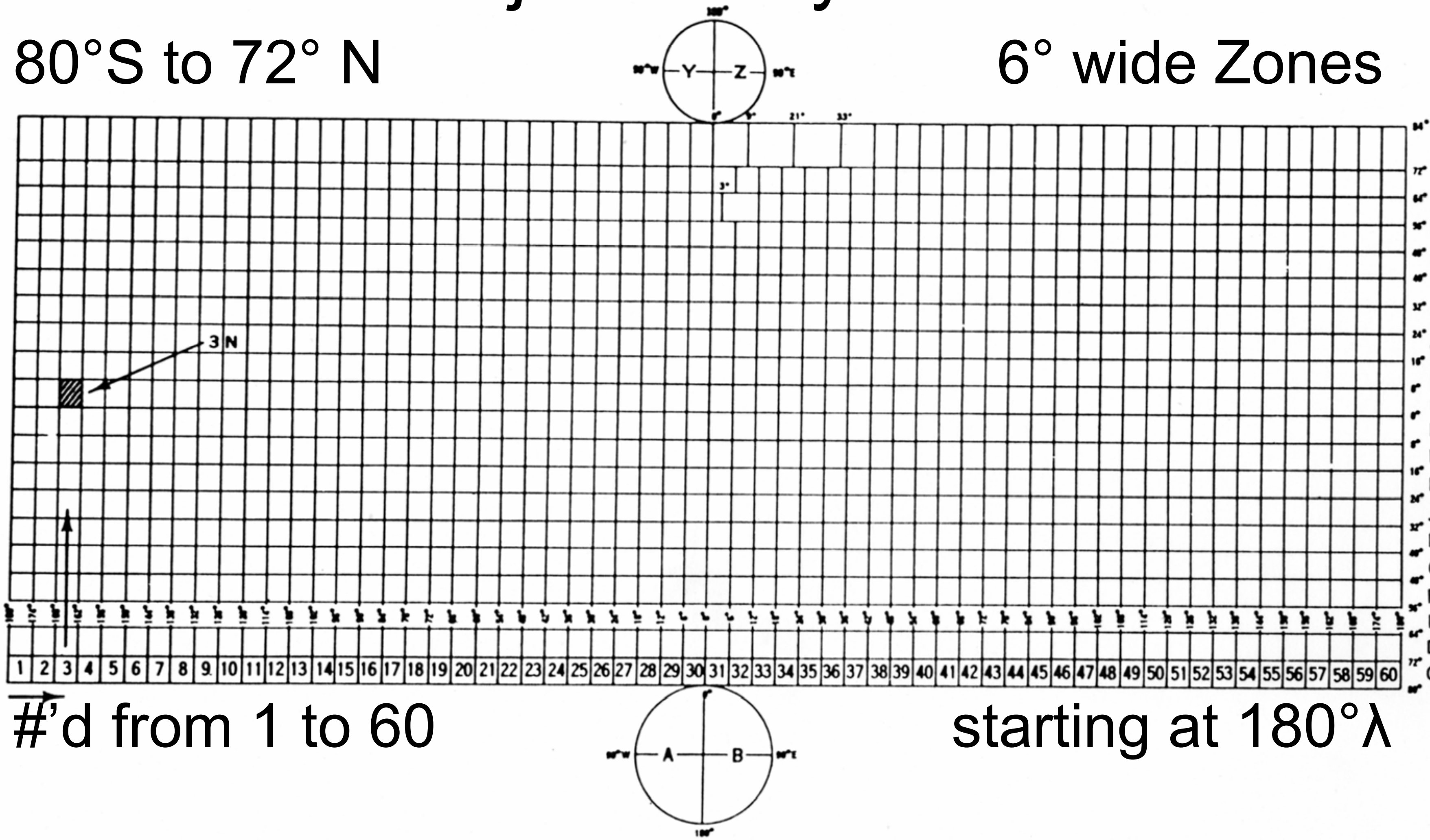
Cross-section view of projection



3b. Universal Transverse Mercator Projection System:

80°S to 72° N

6° wide Zones



#'d from 1 to 60

starting at 180°λ

FIGURE 11.–Universal Transverse Mercator (UTM) grid zone designations for the world shown on an Equidistant Cylindrical projection index map.

3b. Universal Transverse Mercator Projection System :

(6° Zones)

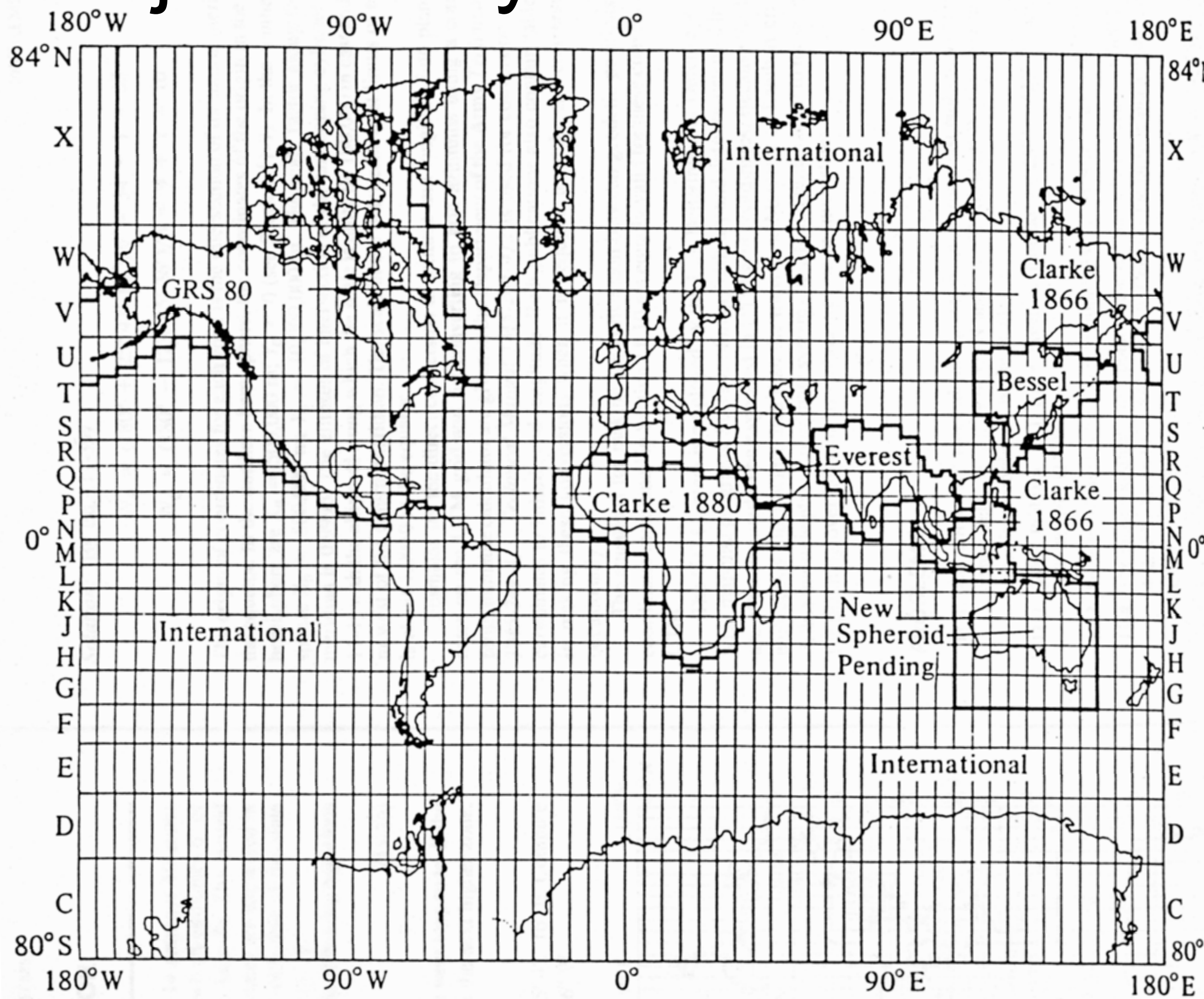
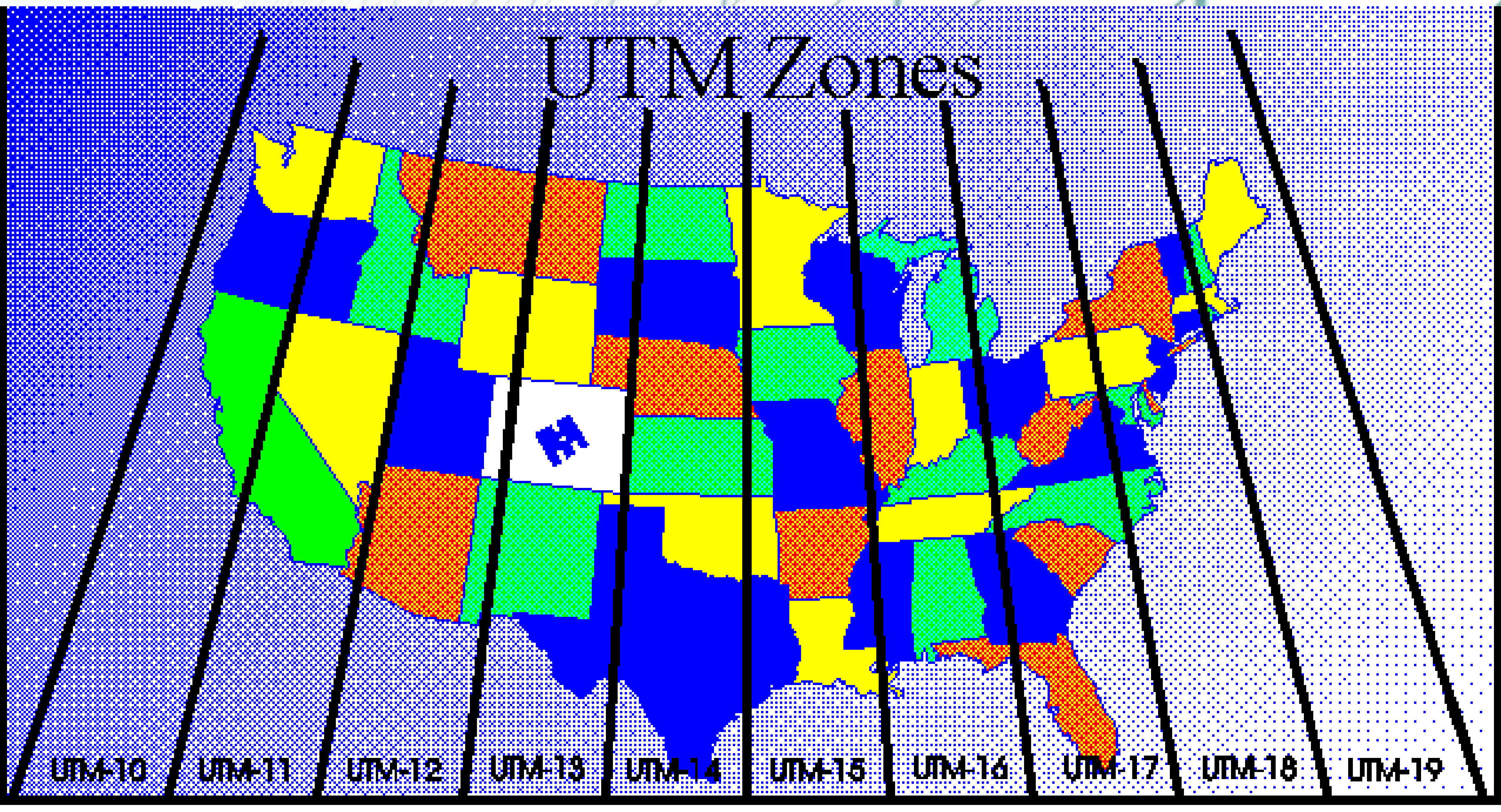


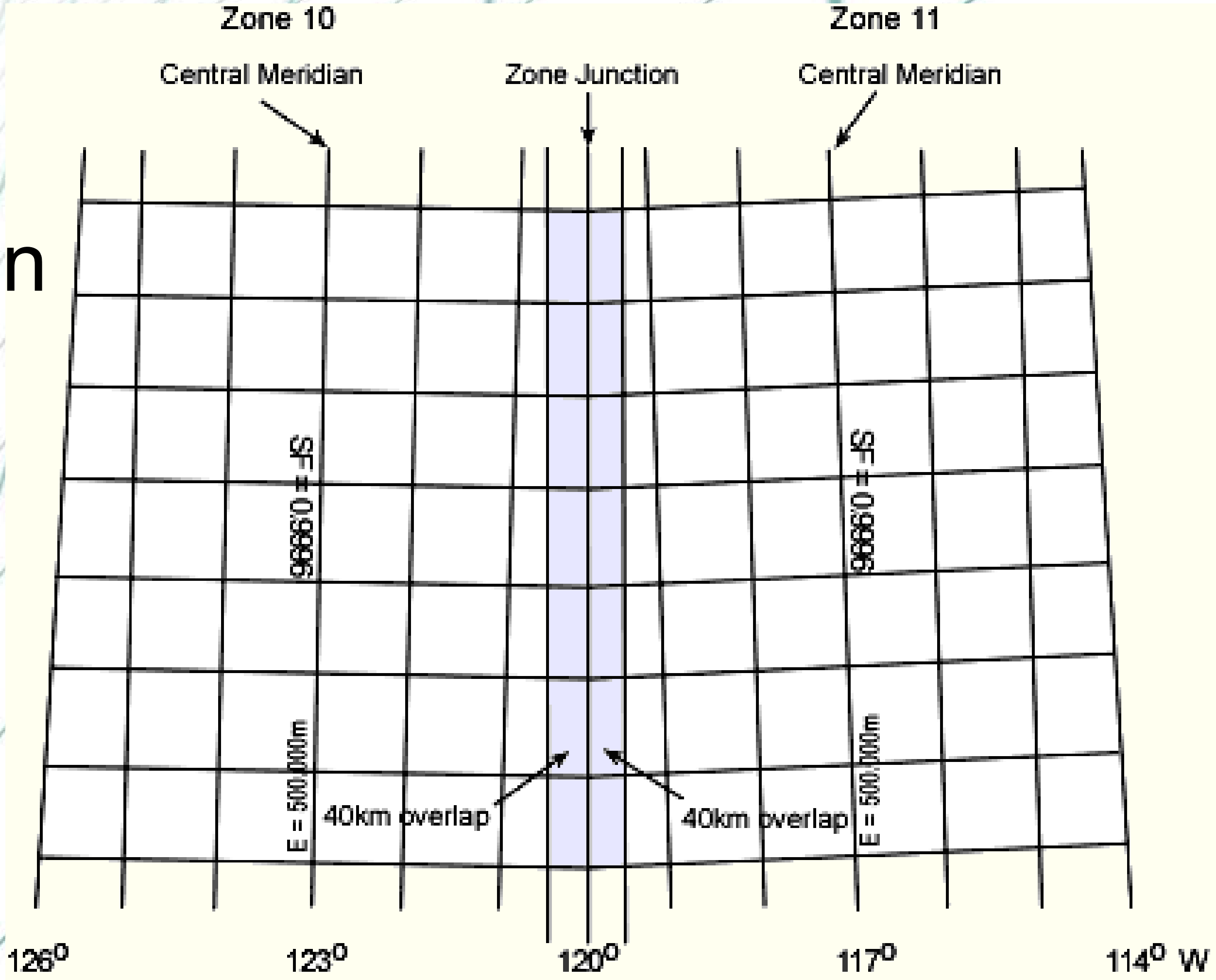
FIGURE 11-14 Universal transverse Mercator (UTM) system. The zones are numbered from 1 to 60 eastward from 180° west longitude.

3b. Universal Transverse Mercator Projection UTM Zones in lower 48 states



3b. Universal Transverse Mercator Projection System (6° Zones):

Each zone has
a Central Meridian
with
An Easting
of 500,000 m



3b. Universal Transverse Mercator Projection System (6° Zones) :

In Northern Hemisphere:

Northing (Y) = 0

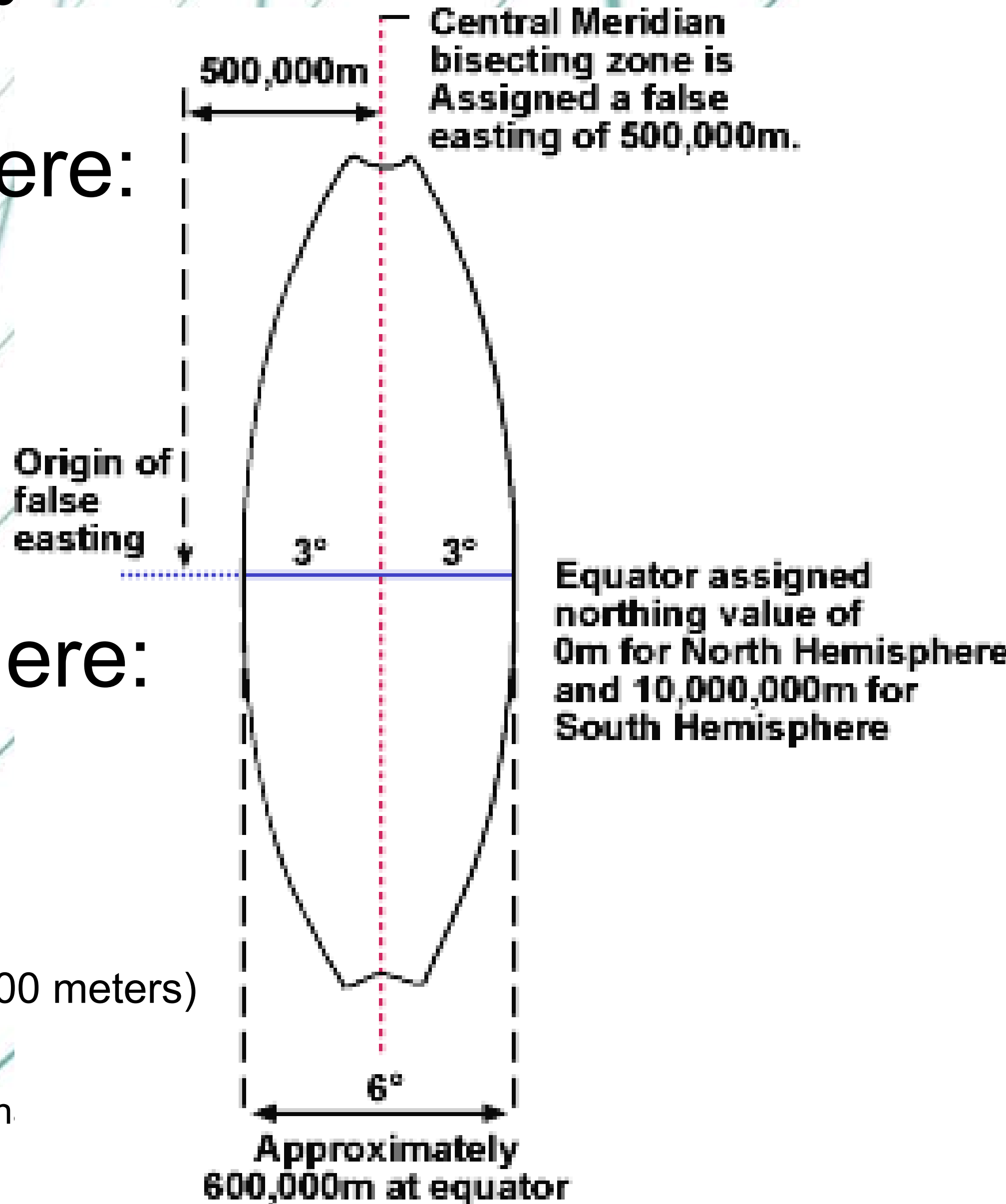
At the equator

In Southern Hemisphere:

Northing (Y) = 0

At the South Pole

(equator given a false nothing of 10,000,000 meters)



Universal Transverse Mercator Projection

NH in two different zones, 18 & 19

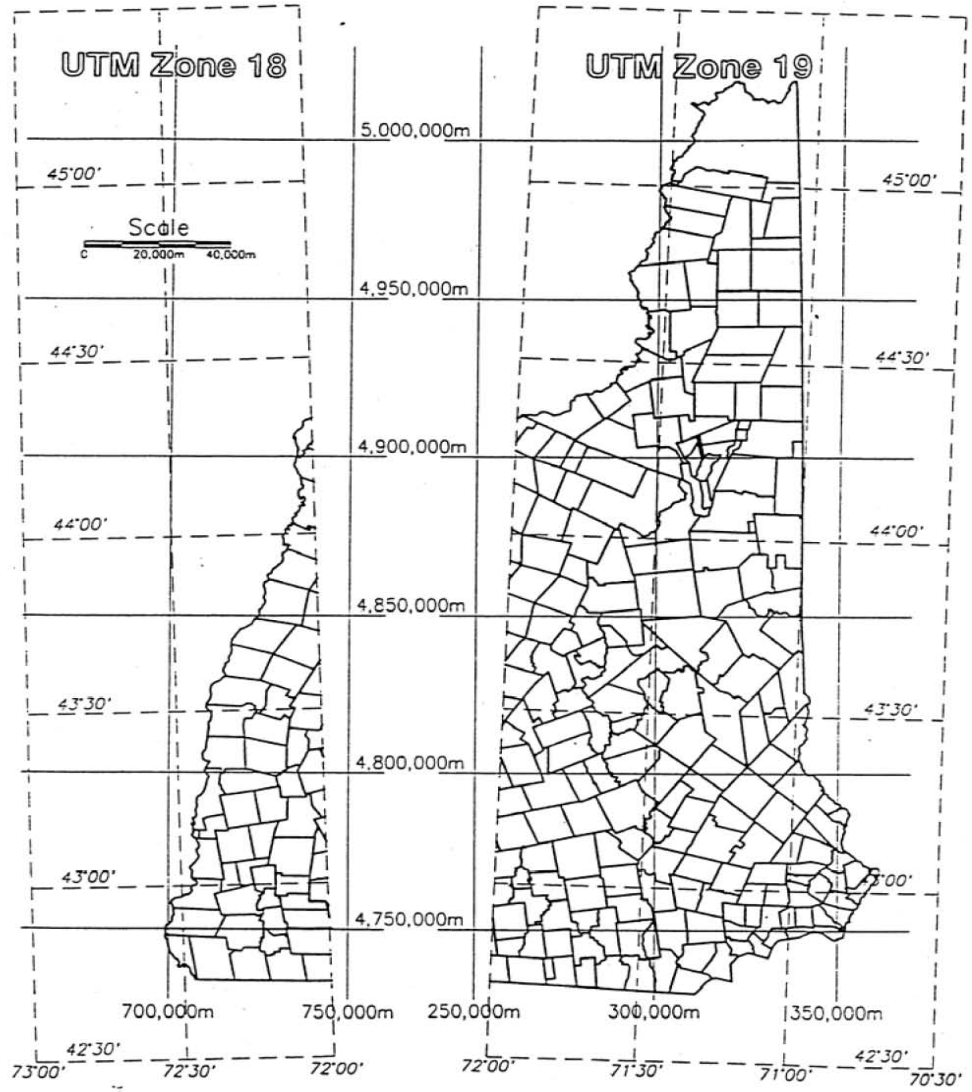


Figure 2.7 - State of New Hampshire (state and town boundaries), in UTM coordinates, Zones 18 and 19. Coordinate grid units are in meters.

3c. The United States National Grid (USNG)

- An alphanumeric point reference system that overlays the UTM System
- Similar to the US Military Grid Reference System (MGRS)
- Is the FGDC Standard
- Is the Department of Homeland Security recommended system

3c. The Unites States National Grid (USNG)

GZD's

6°Long. By 8°Lat. Quad-rangles

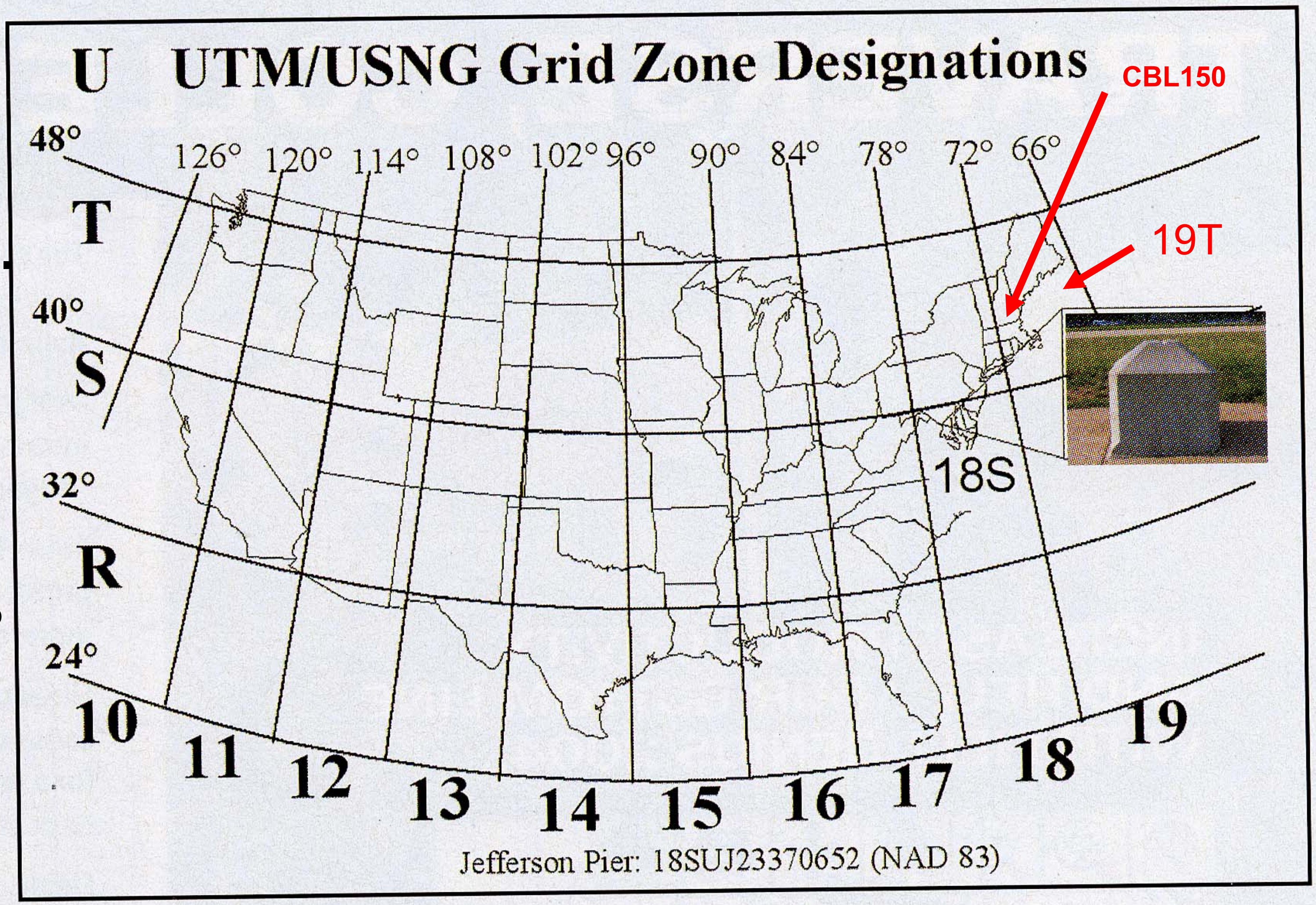


Figure 5 USNG Grid Zone Designations over the conterminous United States.

Prof. Surv. Magazine

3c. The Unites States National Grid (USNG)

Each GZD has a scheme of 100KM Squares

The ID Designation Is a pair of letters AA through ZV
(no letters I or O used)

FGDC-STD-011-2001

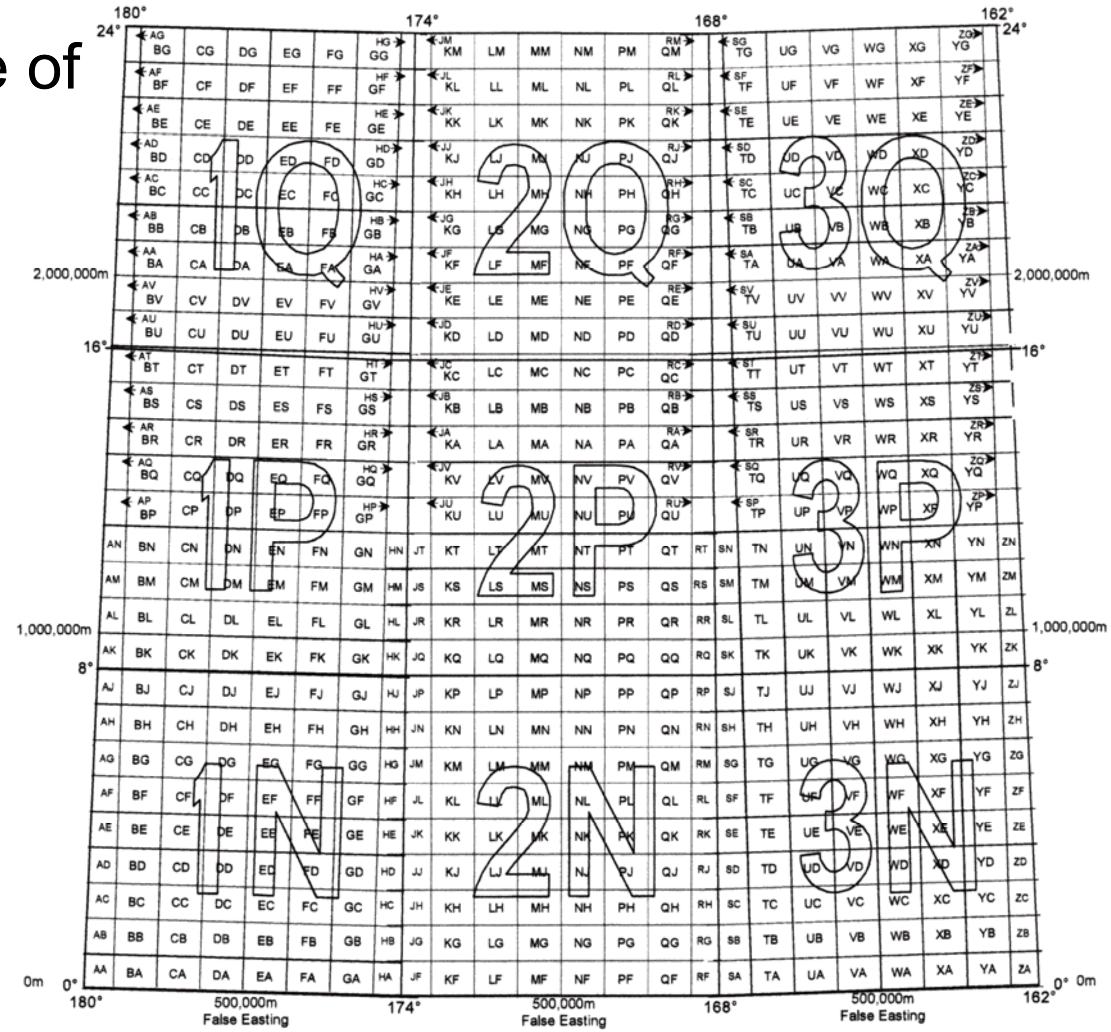


Figure 2. Basic Plan of the 100,000-meter Square Identification of the United States National Grid (USNG)

3c. The Unites States National Grid (USNG)

Plan of 100KM Square ID’s by Zone (SET)

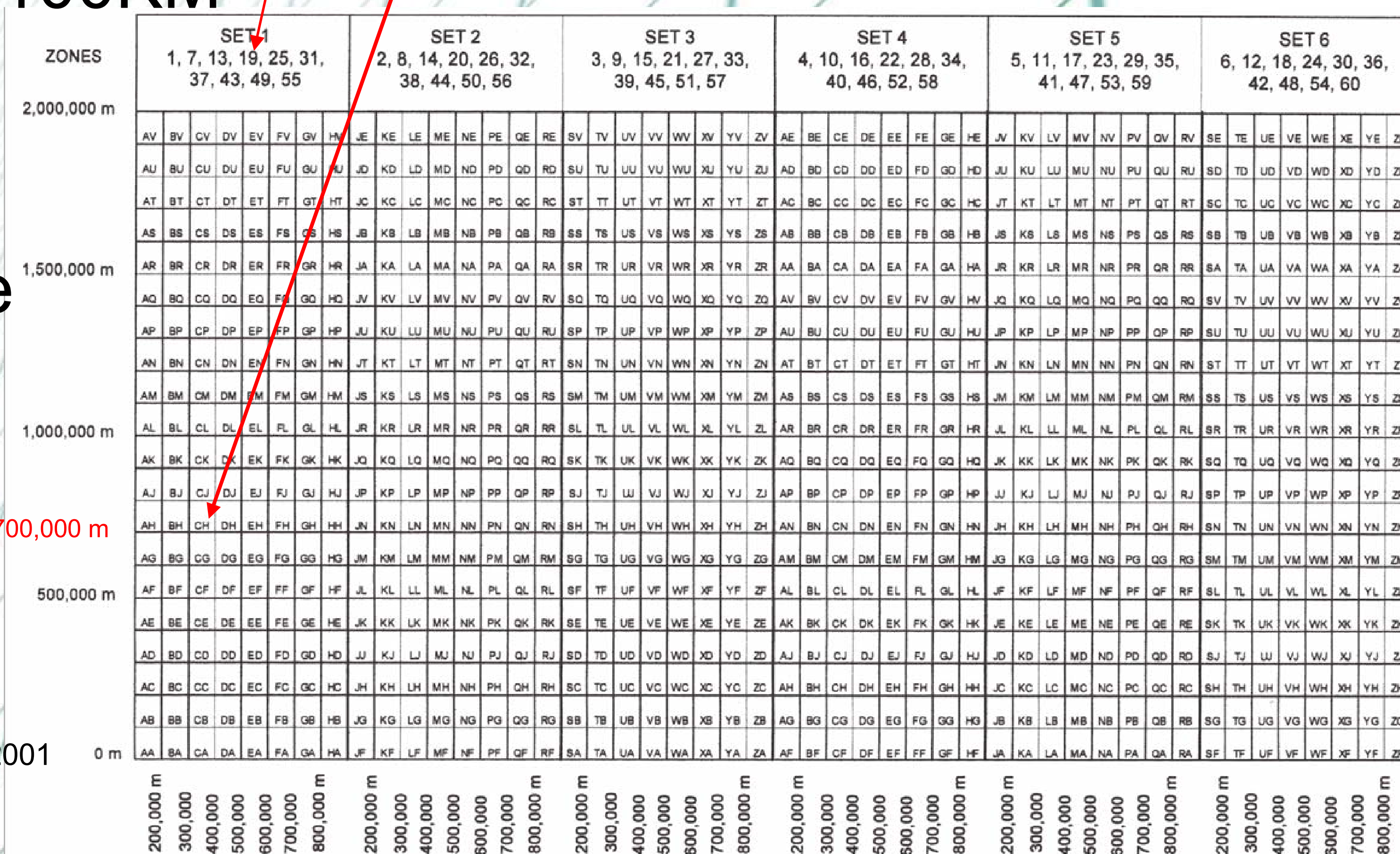


Figure 3. Organization of the U.S. National Grid (USNG) 100,000-meter Grid Squares

FGDC-STD-011-2001

3c. The Unites States National Grid (USNG

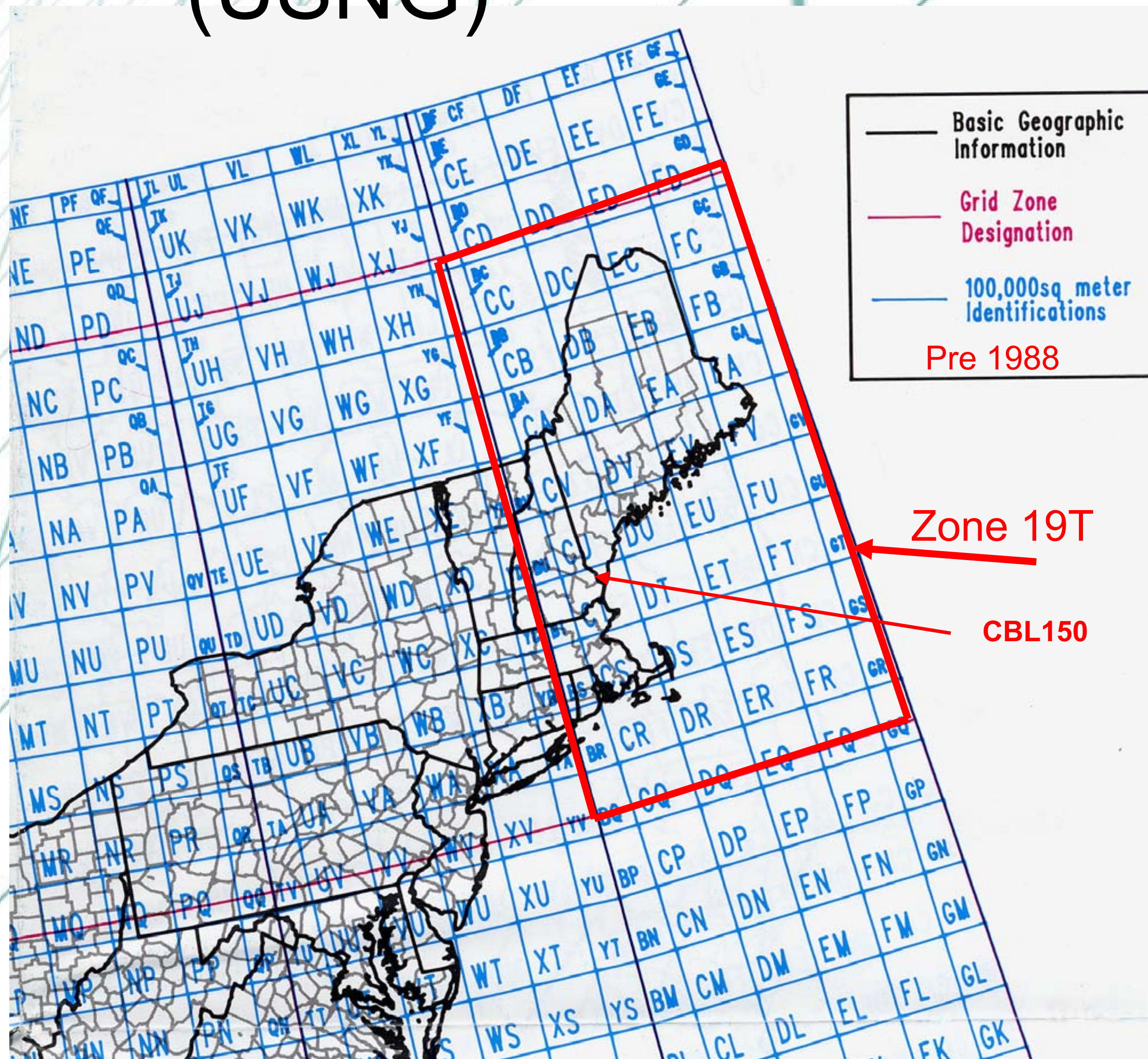
Station CBL150:

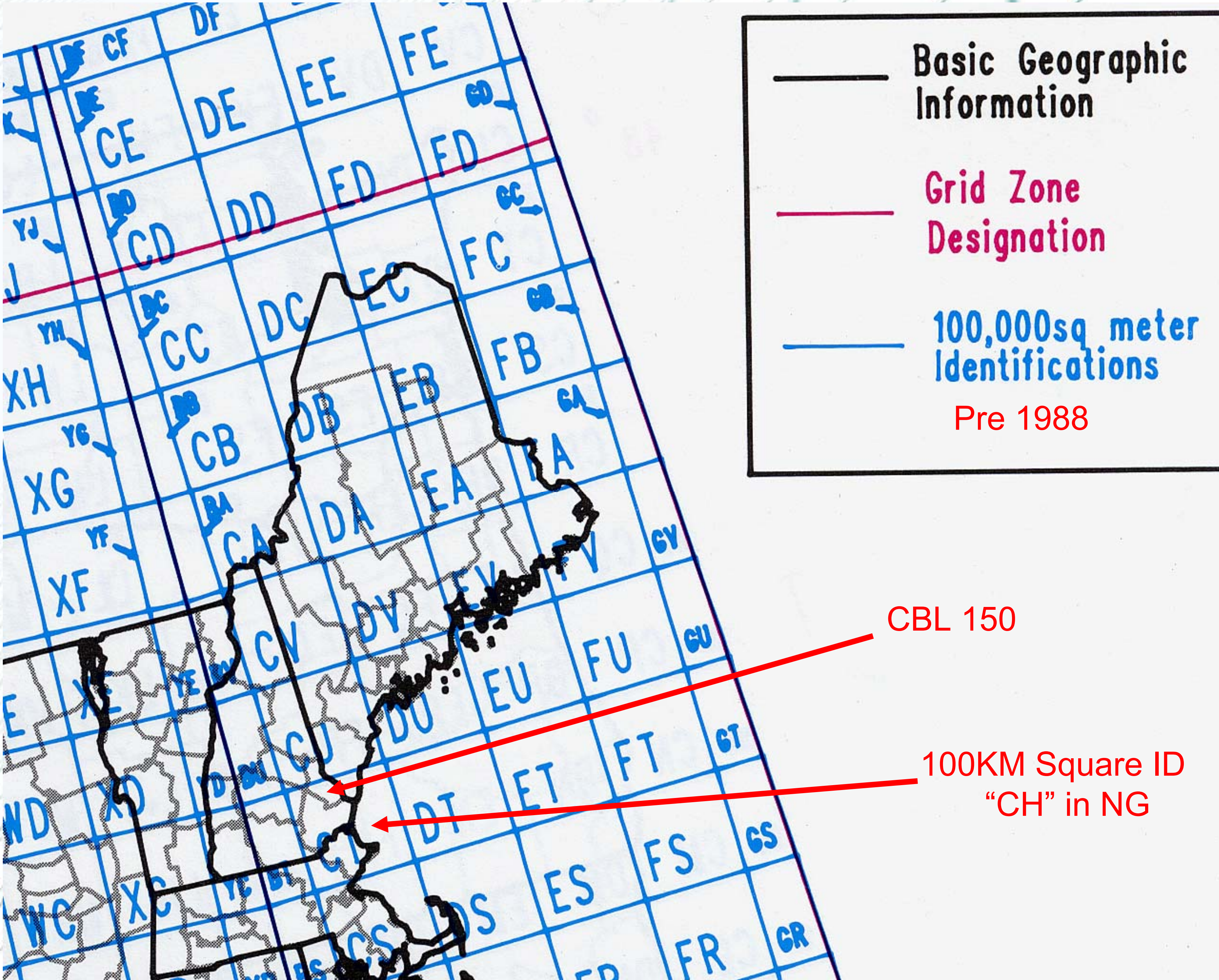
Calibration **B**ase **L**ine **150** (meters)
UNH – Durham, N.H.

3c. The Unites States National Grid (USNG)

Example of 100,000 meter square ID In NE.

The ID Designation Is a pair of letters AA through ZV (no letters I or O used)




Basic Geographic Information
Grid Zone Designation
100,000sq meter Identifications
Pre 1988
CBL 150
100KM Square ID
“CH” in NG

3c. The Unites States National Grid (USNG)

So a USGN Geoaddress consists of:

1- **Grid Zone** Designation (GZD):
two digits and one letter (19T)
(C to X, no letter I or O used)

2- **100 km Square ID**:
a pair of letters (AA –ZV) (19T CH)
(no letters I or O used)

3- **Grid Coordinates**:
Easting, Northing (X,Y) in Meters

3c. The Unites States National Grid (USNG)(100 KM Squares) :

Station CBL150:

Calibration **B**ase **L**ine **150** (meters)

UTM Coordinates:

E = 342,180.681 m

N = 4,778,260.946 m

So

USNG Position:

19TCH4218078260NAD83

If 5 coordinate digits, then to nearest meter

If 4 coordinate digits, then to nearest 10 meters

3c. The Unites States National Grid (USNG)

So a USGN Geoaddress consists of:

1- **Grid Zone** Designation (GZD):

two digits and one letter (19T)

(C to X, no letter I or O used)

2- **100 km Square ID**:

a pair of letters (AA –ZV) (19T CH)

(no letters I or O used)

3- **Grid Coordinates**:

Easting, Northing (X,Y) in Meters

(19TCH4218078260)

3c. The Unites States National Grid (USNG)

Another Example:

A point with coordinates:

6**82,725** M East 5,0**91,275** M North UTM Zone 19 NAD83

Would be designated as"

19TFL8272591275NAD83

19T Grid Zone Quadrangle (6° λ by 8° Φ Quadrangle)

FL 100 KM Square

82725 Truncated Easting

91275 Truncated Northing

NAD83 The Horizontal Datum used in the projection

3c. The Unites States National Grid (USNG)(100 KM Squares) :

A third example:

The Jefferson Pier:

Planned to be the First Meridian Of the US

18S UJ 2337 0652

Prof. Surv. Magazine

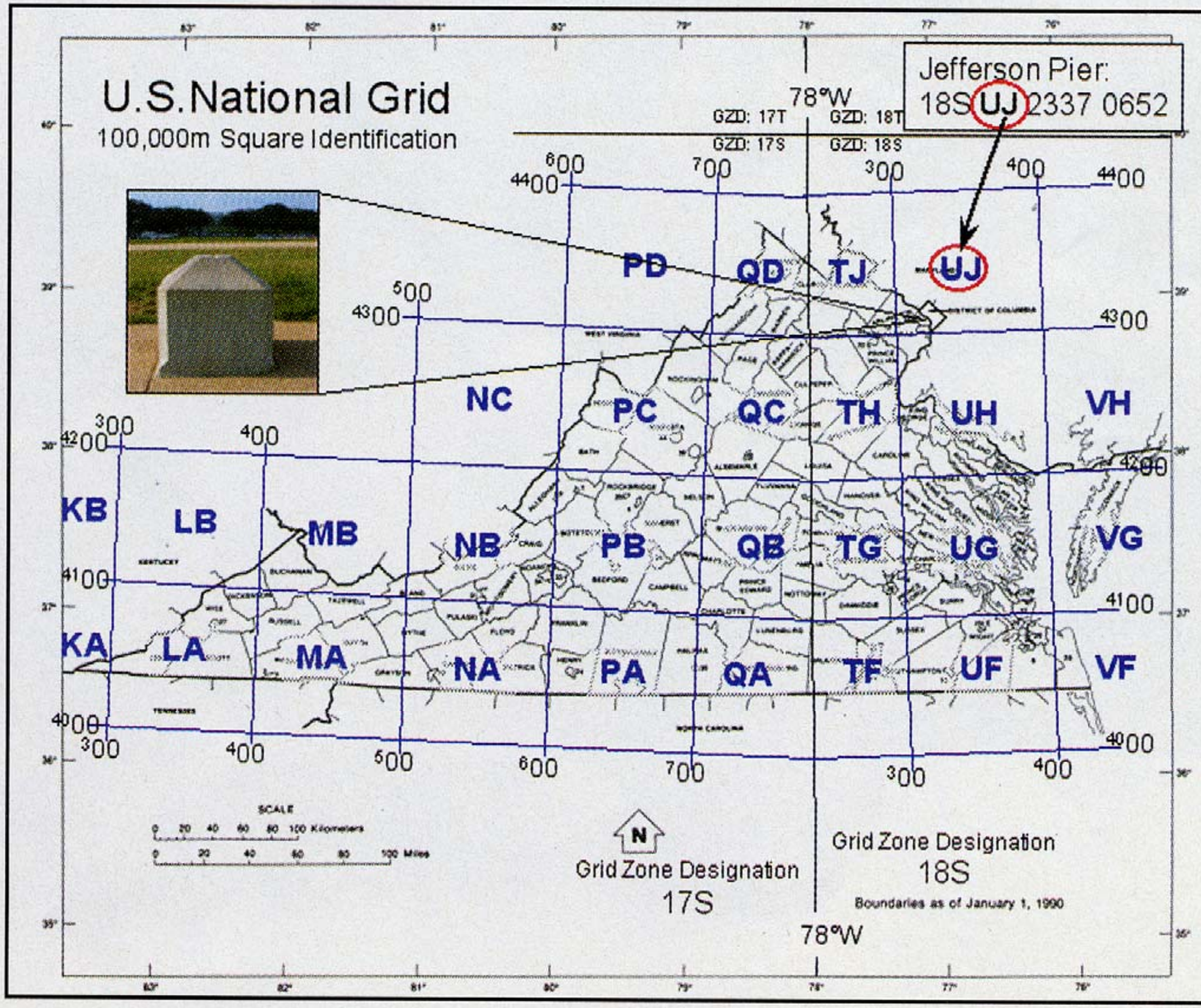


Figure 3 The USNG 100,000-meter Square Identification scheme over Virginia

The Jefferson Pier

Read

"*The Jefferson Stone*"

1999

By Silvio A. Bedini

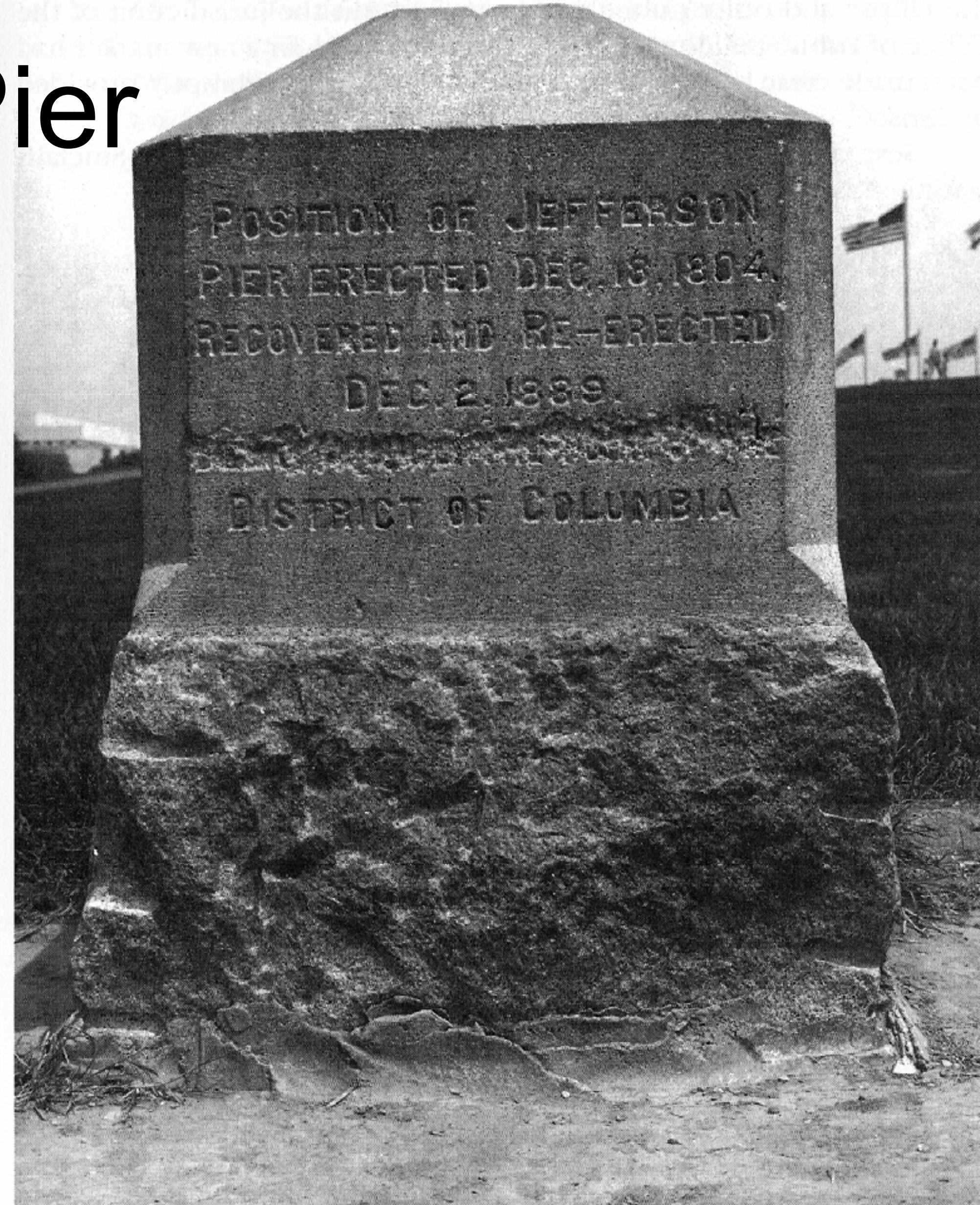


Figure 38. The west face of the Jefferson Pier Monument as it appeared in 1975. Since then the area surrounding it has been regraded to raise the soil level.

Coc

The Jefferson Pier

"*The Jefferson Stone*"
1999
Silvio A. Bedini

Figure 43. The Jefferson Pier Monument. Photograph by Leandra A. Bedini.

3c. The Unites States National Grid (USNG)(100 KM Squares) :

The Jefferson Pier:

18S UJ 2337 0652

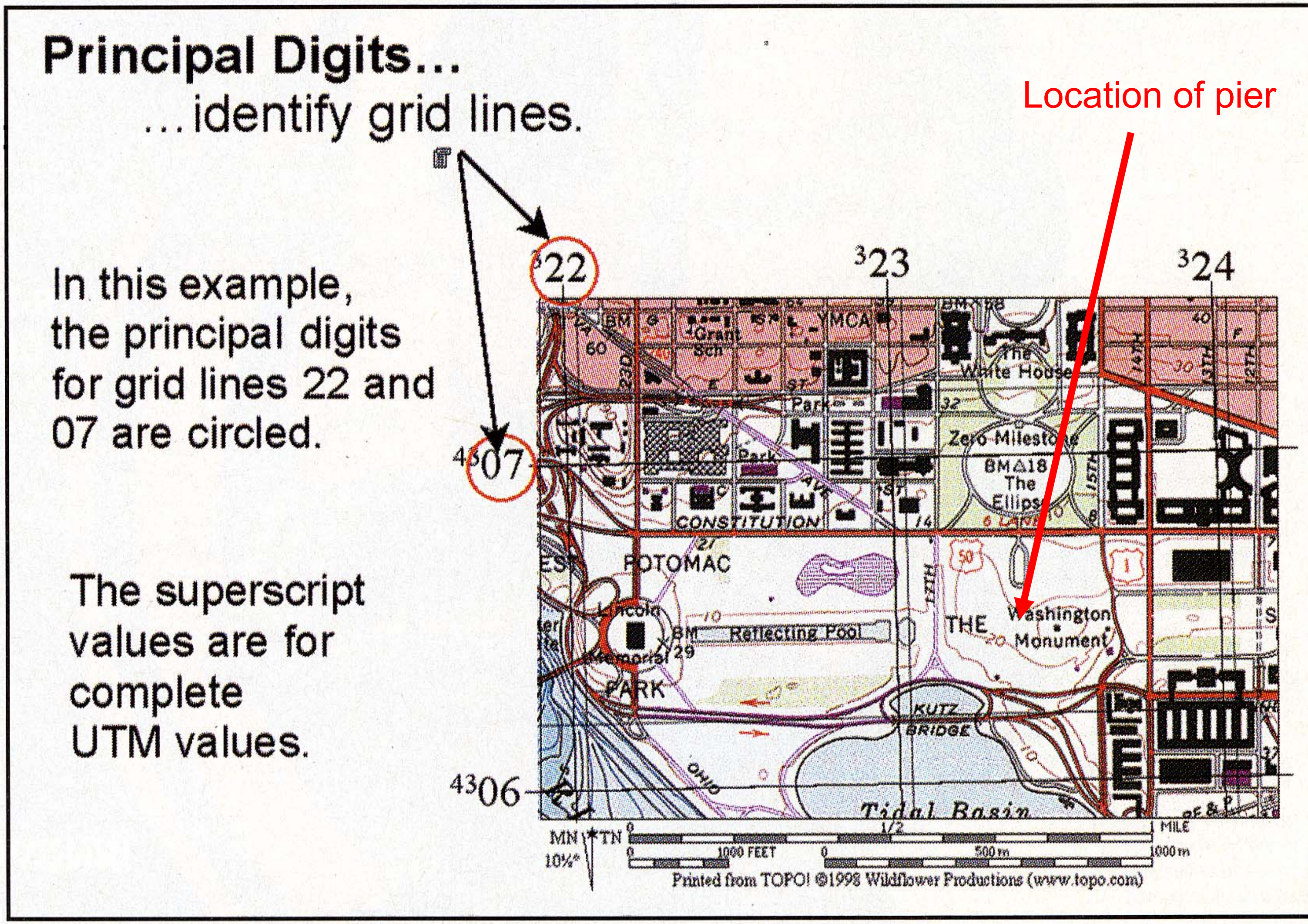


Figure 1 Principal Digits identify grid lines

Prof. Surv. Magazine

THREE DISTANCES

THREE DISTANCES

1. GROUND DISTANCE

   Slope distance between two points

2. ELLIPSOID (GEODETIC) DISTANCE

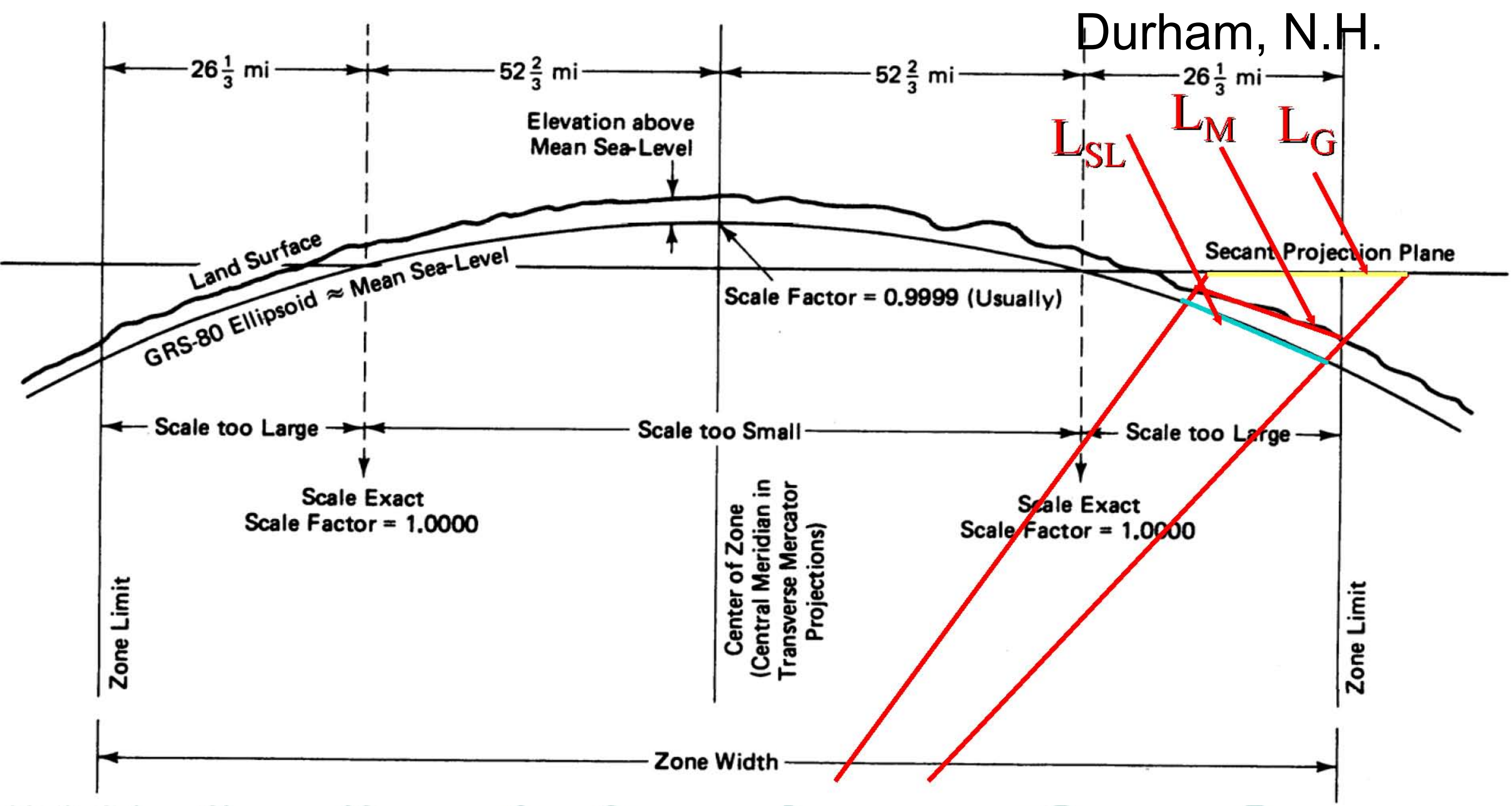
   Curved distance on Ellipsoid between two points

3. GRID DISTANCE

   Horizontal distance on Plane between two points

Ground – Ellipsoid - Grid Distances

L_{SL}= Sea Level (Geodetic) Dist. L_M= Ground Dist. L_G= Grid Dist.

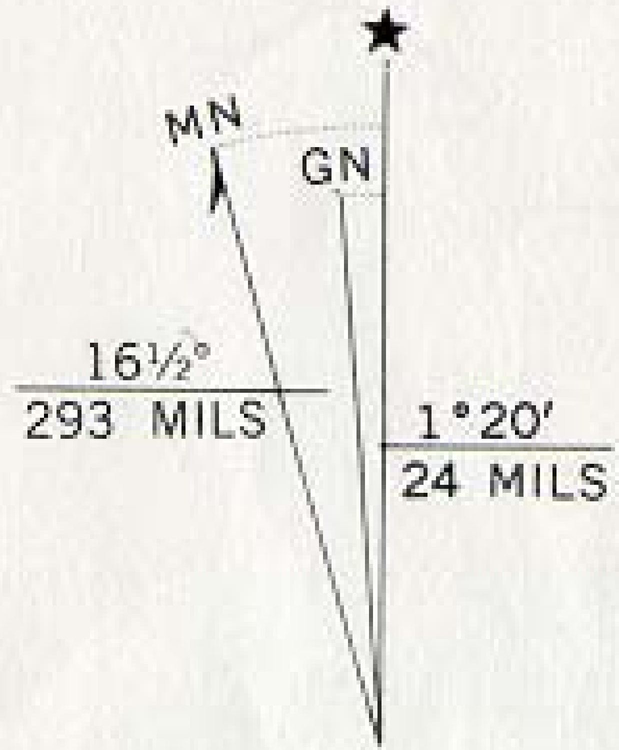


FIVE NORTHS

FIVE NORTHS

1. Astronomic North
   Based on Earth's Rotation Axis
2. Geodetic North
   Based on Ellipsoid's Rotation Axis
3. Grid North
   Based in Central Meridian of System
4. Magnetic North
   Based on magnetic lines of force
5. Assumed North
   Based on any convenient axis

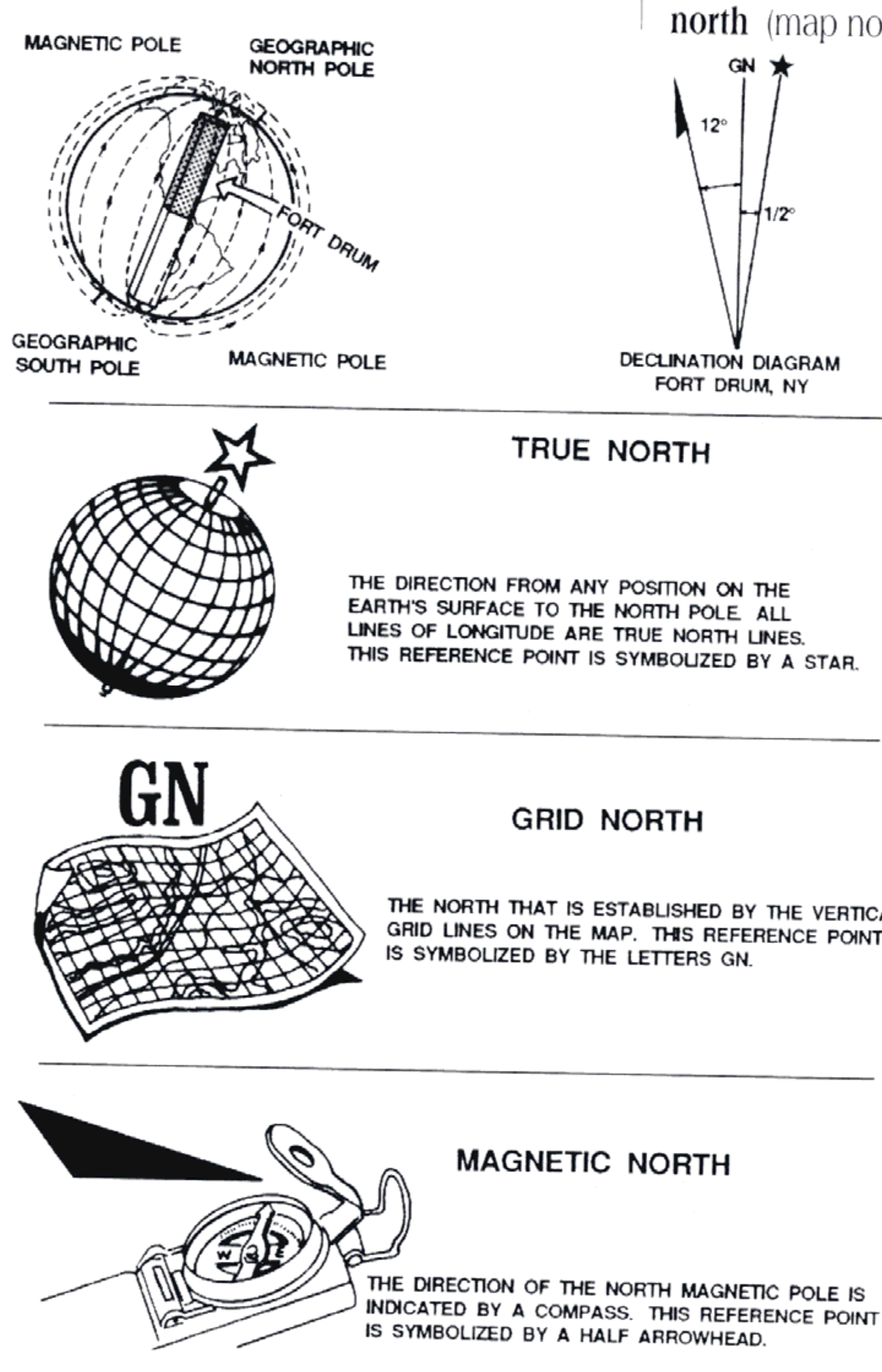
Geodetic –Grid –Magnetic North



blue

UTM GRID AND 1993 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

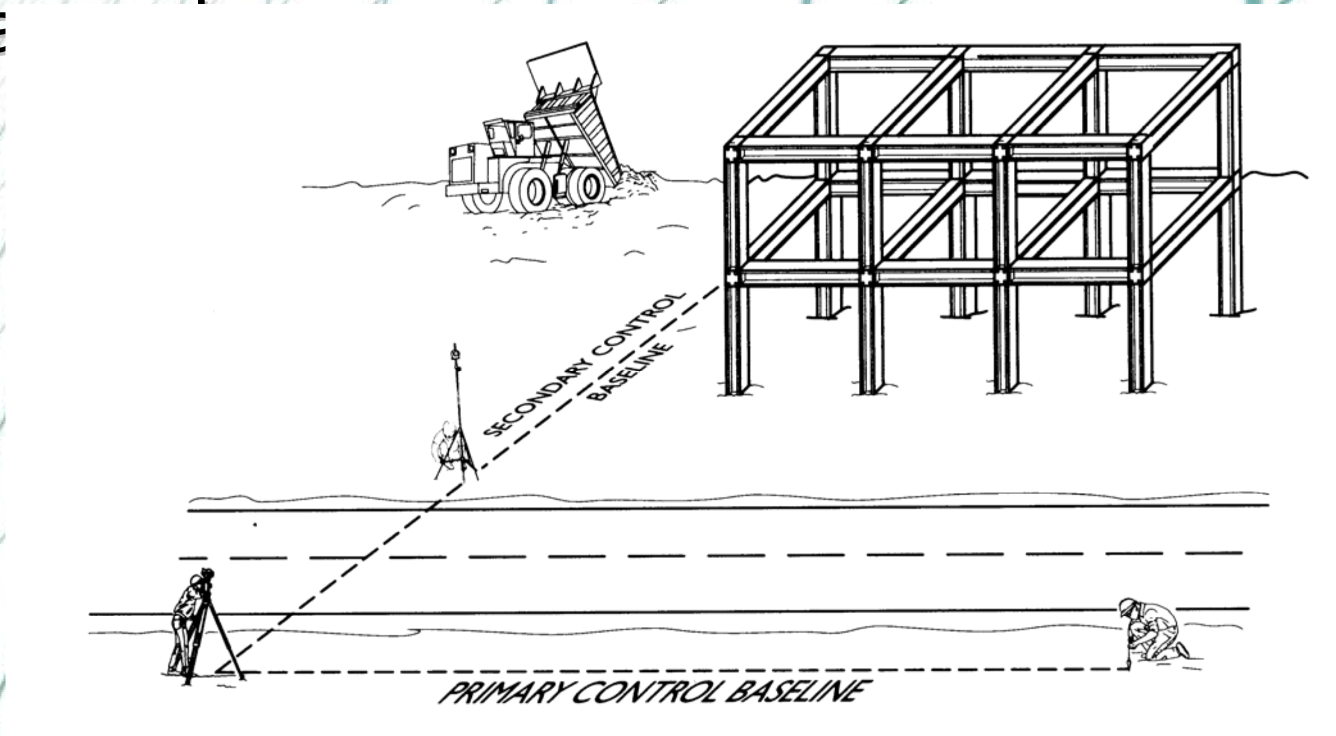
Other Map Information: Norths



Assumed North

Assumed Coordinate System

Using any arbitrary direction (Building column line, center of pipeline, etc.) as a reference meridian from which directions (angles) will be mea



RECAP OF PRESENTATION OUTLINE

- 4 SURFACES
- 3 HEIGHTS
- 2 DATUMS
- 4 COORDINATE SYSTEMS
- 3 DISTANCES
- 5 NORTHS

RECOMMENDED SYSTEM TO USE FOR MUNICIPAL BOUNDS

N.H. STATE PLANE COORDINATES, NAD 83 (FEET OR METERS)

OR

LATITUDE(ϕ), LONGITUDE (λ), NAD 83