PART IV: COORDINATES AND MAP PROJECTIONS

4.1 Introduction

As it is well known, the earth is a spherical surface. For most small-area projects, surveyors treat the earth as a plane. The differences between the relationships of features that are depicted on the plane and their actual position on the earth are insignificant. In addition, the advantage of this approach is that it simplifies the computations. But for large-scale projects, it is critical that the curvature of the earth be taken into account. On the plane, the distortions in distance and directions become very extreme very quickly.

The process of obtaining plane coordinates from a spherical coordinate system involves projecting the lines of latitude and longitude on the earth onto a surface that is either a plane or a surface that can be developed into a plane. For mapping purposes, the process is usually performed in three steps. First, the earth is scaled to the appropriate-scaled globe. Next, the projection surface is fit to the globe and the points are projected onto this surface. Finally, the projection surface is generally "flattened". This process is a transformation that is referred to as a map projection. In surveying applications, the surface is the earth and no reduced scale globe is created.

4.2. Types of Map Projection

Figure 4.1
Orthographic Projection.

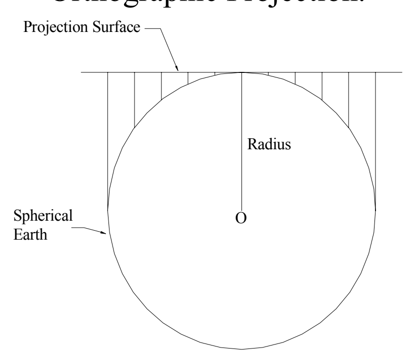
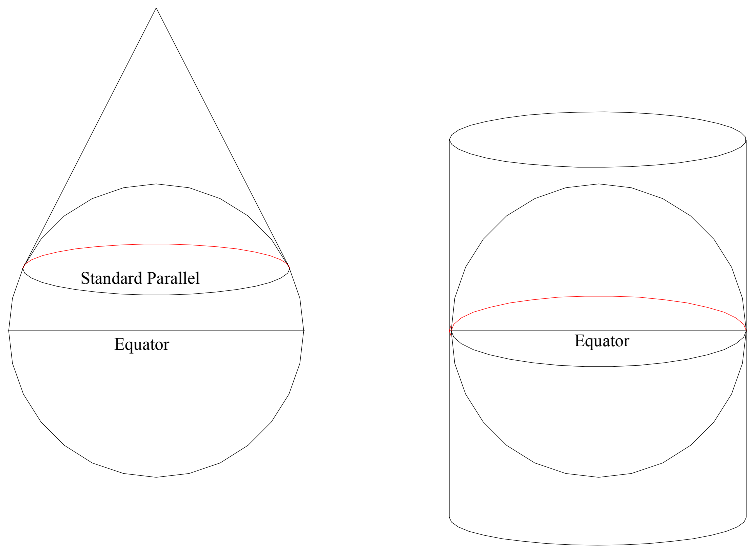


Figure 4.1 shows the effects of having a plane projection surface that is tangent to the sphere. As one moves farther away from the center, the distance on the projection surface remains the same but the corresponding distance on the spherical surface becomes greater. Thus, another type of surface needs to be considered to control the distortions that accrue.

Two surfaces can be used very effectively. These are the cone and the cylinder as shown in figure 4.2. In this case, both surfaces are tangent to the sphere. They can be developed into a plane surface by cutting the cone or cylinder and flattening the figure. Being a tangent projection, there is only one line of contact between the earth and the projection surface. Distortions will become significant the farther a feature is from this line of contact. To compensate for this, a secant projection can be employed as shown in figure 4.3. Here the cylinder or cone intersects the surface of the earth thereby creating two lines of contact. The beauty of these types of projection surfaces is that the distortions between the two lines of contact are less than 1.0 while those beyond are greater than 1.0. Along the line of contact, the scale factor is 1:1.

Figure 4.2
Conical and cylindrical projection surfaces.

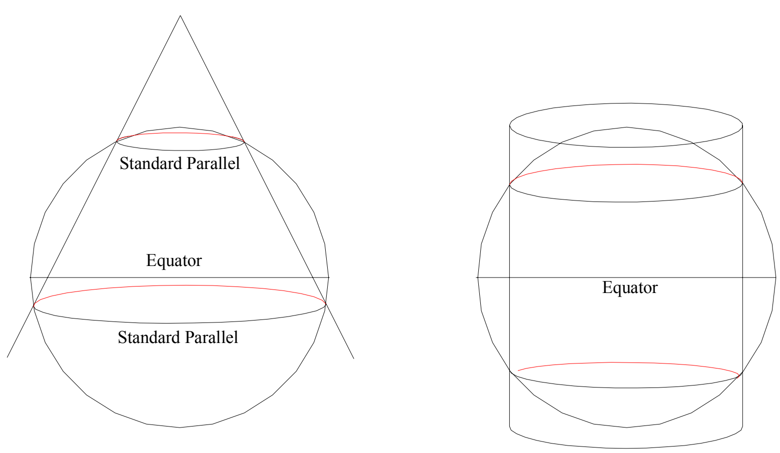


All map projections, by their nature, will cause distortions. These distortions include: distance, area, directions, and angles. It is possible to minimize one of these types of distortion in a single projection system. Thus, four different classes of map projections can be defined:

1.2. Conformal projection where the shape is preserved. This means that angles will retain their correct values.
1.3. Equivalent projection which preserves the area on the map as its proper size. It's shape, on the other hand, could be greatly distorted.
1.4. Equidistant projection holds the distances correct.
1.5. Azimuthal projection is one where the correct azimuth or direction is preserved in the transformation process.

A map projection cannot be conformal, equivalent and equidistant. These three properties are mutually exclusive meaning that a projection can only hold one of these properties. An azimuthal projection can coexist with one of the preceeding three properties. Thus, it is possible to have a conformal and azimuthal projection, or an equidistant and azimuthal projection. It is also important to realize that these properties are only valid for differentially small areas where there exists a 1:1 relationship between the projection surface and the earth. For example, an equidistant projection does not mean that all distances on the map will be without distortion.

Figure 4.3
Conical and cylindrical projection surfaces using a secant projection.



4.3. Conformal Mapping

Conformality means that angles are preserved between any short line segments on the projection surface. Normally in conformal mapping a new surface is introduced called the isometric plane. This is an intermediate surface used to relate the geodetic latitude and longitude (, λ) to rectangular coordinates (X, Y). The isometric latitude is often shown to be:

$$q = \frac{1}{2}\left(\ln\frac{1+\sin\varphi}{1-\sin\varphi} - e\ln\frac{1+e\sin\varphi}{1-e\sin\varphi}\right)$$

where e is the eccentricity defined as $e^2 = \frac{(a^2 - b^2)}{a^2}$.

The variables a and b represent the semi-major and semi-minor axes of the ellipse respectively.

4.4. Lambert Conformal Conic Projection

The Lambert Conformal Conic Projection was initially developed by Johann Heinrich Lambert. It uses a secant cone that passes through the ellipse through two lines called the standard parallels, This is shown in figure 4.4. As shown in the figure, the distortions are a function of the latitude. In other

Figure 4.4
Secant cone used in the Lambert Conformal Projection.

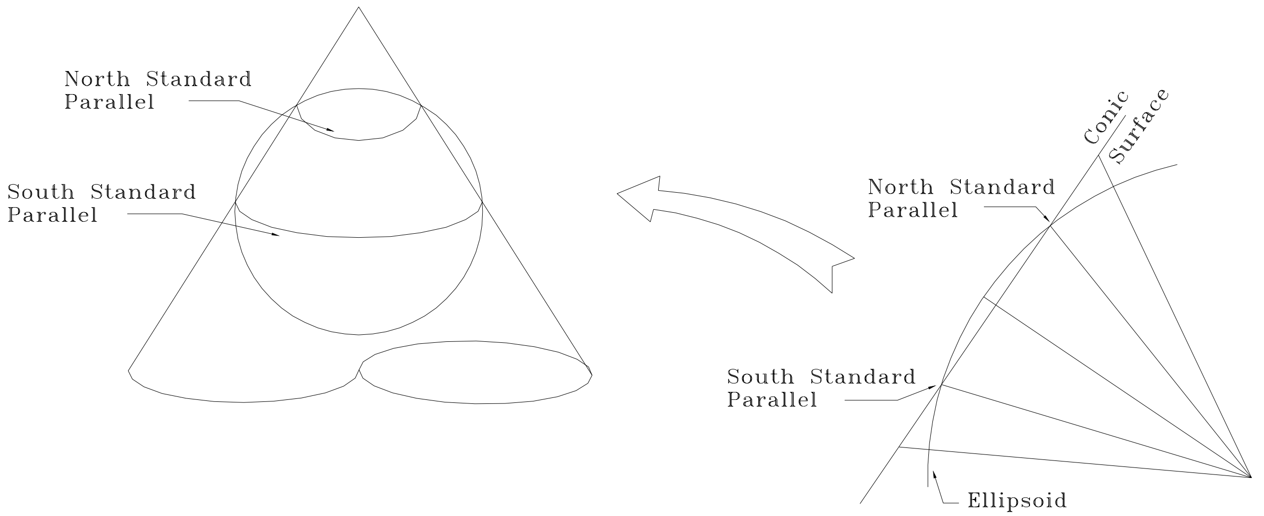
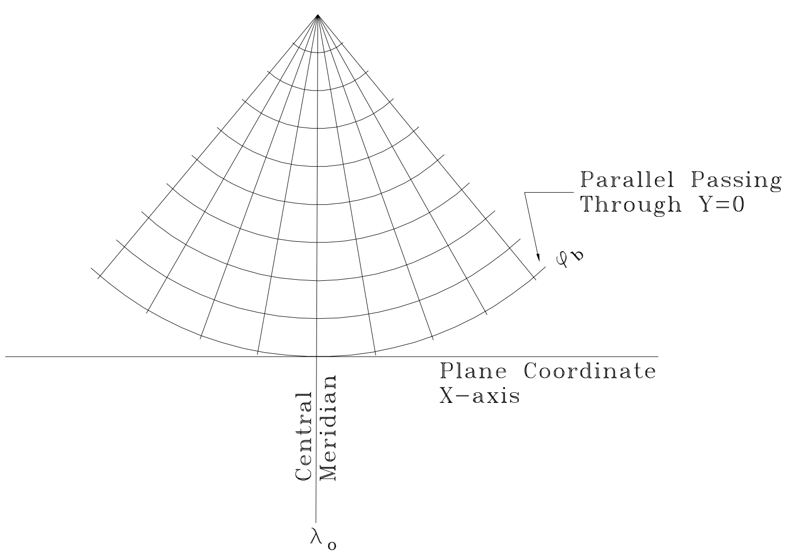


Figure 4.5
Projection of meridians and parallels on the Lambert Conic Projection.



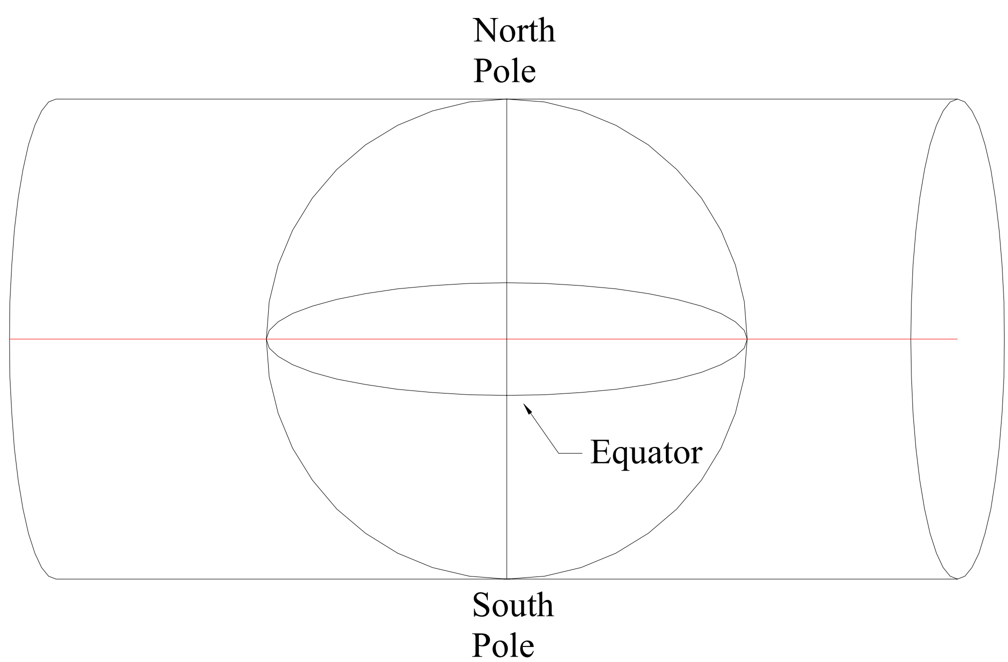
words, the farther the location of a point from the line of contact, the more the effects of the distortion. Therefore, this projection is ideal for areas that have a predominant east-west extent. Meridians on this projection are straight lines that meet at the apex of the cone which is outside the projection area (figure 4.5). Parallels are projected as concentric circles about the apex. The meridians and parallels intersect at 90°.

4.5. Universal Transverse Mercator Projection (UTM)

The Universal Transverse Mercator Projection is cylindrical projection where the axis of the cylinder is perpendicular to the rotational axis of the earth (figure 4.6). The system is a world-wide system with the following specifications:

1. The zones are 6° wide in longitude, each of which are based on the Transverse Mercator projection formulae.
2. The GRS 80 ellipsoid parameters are used throughout.
3. The zones are numbered from the 180°W longitude to the east. Thus, there are a total of 60 zones covering the complete globe.
4. The latitude extent of each zone is from 80° S to 84° N latitudes
5. Each zone is divided into 8° sections, except for the last section to the north which is 12° north-south.
6. The origin of each zone is the intersection of the central meridian with the equator.
7. A false easting value of 500,000 meters is assigned to the central meridian of each zone.
8. A false northing of 10,000,000 meters at the equator is used for the southern hemisphere while the northern hemisphere has a value of 0 meters at the equator for the northing.

Figure 4.6
Transverse Mercator Projection.



4.6. State Plane Coordinates Using the Lambert Projection

The purpose of the State Plane Coordinate system is that it allows the surveyor to use plane coordinates for projects that have a large extent which, in turn, requires that the curvature of the earth be considered in the mapping project. It allows the surveyor to use normal traverse reduction procedures which they are already familiar with. On the other hand, there are a few preliminary reductions for traversing that is required. These are outlined as follows:

1.1. Determine the starting and ending azimuths for the project.
1.2. Determine the grid scale factor. Depending on the scope of the project, a single grid scale factor can be used, but larger projects may require the determination of the grid scale factor for each line.
1.3. Determine the elevation factor for the project. Again, a mean elevation factor may be adequate for a particular project whereas some projects may require the computation of a mean elevation factor for each line.
1.4. Compute the combined grid scale factor and elevation factor.
1.5. Reduce the distances measured in the field to horizontal distances and then project them onto the grid.
1.6. Compute the approximate coordinates of the points using the unreduced angles and grid distances.
1.7. Look at the t-T correction factor and if the magnitude is significant, apply this correction to each angle using the approximate coordinates already determined.
1.8. Adjust the traverse as normal.
1.9. Compute the final adjusted state plane coordinates, distances, and azimuths between the point. It may also be useful to compute the ground distances as well.

4.7. Point Scale Factors and Elevation Factors on the Lambert Projection

As we can see from figure 4.4, the relationship between the ellipsoid and the cone varies through the projection zone. Figure 4.7 also shows that the scale is too small between the standard parallels and too large beyond the standard parallels. The grid scale factor is the distortion that occurs when projecting the ellipsoid position onto a plane. This scale factor is designated as “k” and it is constant only at that point. In other words, k will vary from point to point. Along the standard parallels, the scale factor is 1.0. Between the standard parallels, k will be less than 1.0 while beyond the scale factor is greater than 1.0.

In section 4.6, it was pointed out that one of the first tasks in data processing was the reduction of distances to the ellipsoid (this is sometimes called the reduction to geodetic distance). The geometry is shown in figure 4.8. This diagram is shown for simplicity in presenting the reduction of ground distances to the ellipsoid. In Michigan, the ellipsoid is above the geoid. The reduction is given as:

Figure 4.7
State Plane Coordinate System distortion areas.

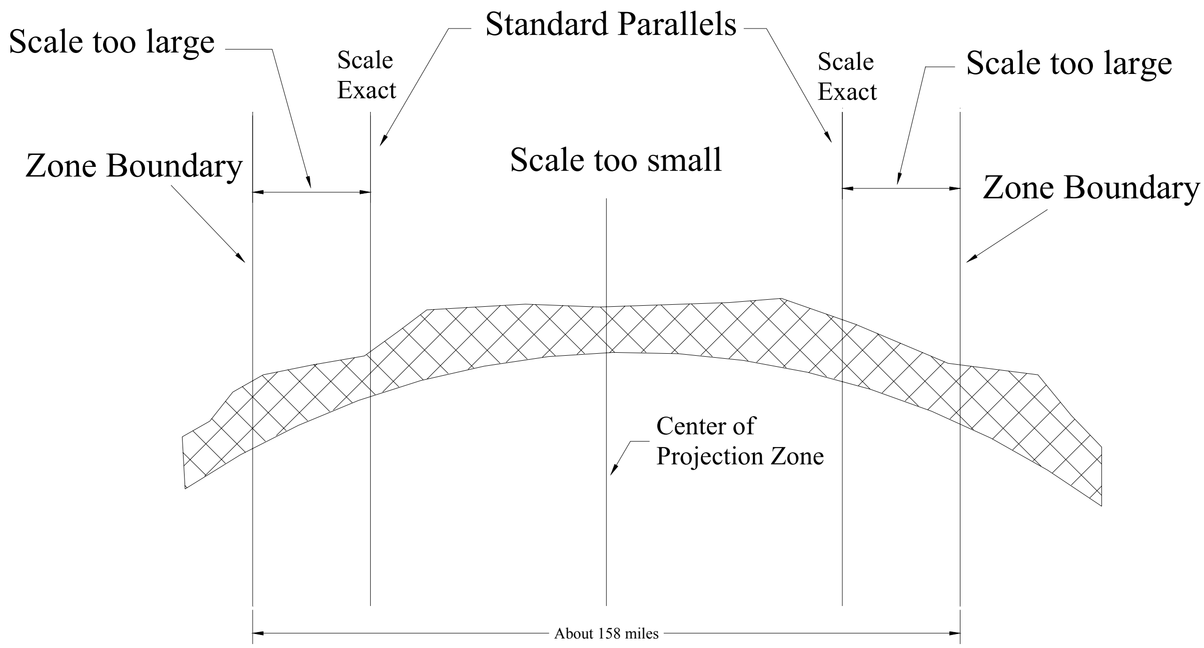
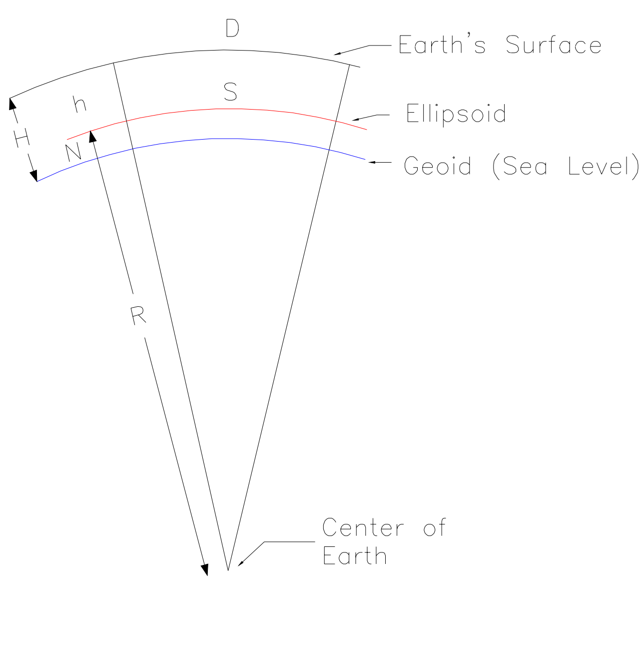


Figure 4.8
Reduction to the ellipsoid.



$$S = \frac{RD}{R + N + H} = \frac{RD}{R + h}$$

where: S is the geodetic distance

D is the horizontal distance (this is the arc distance between the two points, although the second chord to arc correction in reducing the distance is often negligible)

R is the mean radius of the earth (an approximate value of 6,372,000 meters will give acceptable results

H is the mean orthometric height

N is the mean geoid height

h is the mean ellipsoid height which is defined as h = N + H

The question that is often raised by surveyors is why GPS survey data expressed in state plane coordinates do not agree with the EDM measurements made between the two points. The answer lies in the scale factor. Distances that are either reported by the NGS in their data sheets or reduced to the ellipsoid represent geodetic distances. This means that they follow the curvature of the ellipsoid. Inversing between the coordinates of the ends of the line yields the grid distance. For proper comparison, one of these distances needs to be converted into a similar system. Lets assume that we have two points, A and B, with elevations above the ellipsoid of 237.678 meters and 230.543 meters respectively. Then the elevation factor becomes 1.00003730 for A and 1.00003618 for B. These two scale factors can be averaged for the average elevation factor along the line of 1.00003674. Further, assume that the grid scale factor for these two points, as given in the NGS data sheets, are 0.999823451 for A and 0.999831234 for B. Again, the mean grid scale factor for this line becomes 0.9998272734. The combined factor is the product of the grid scale factor and the elevation factor. Thus,

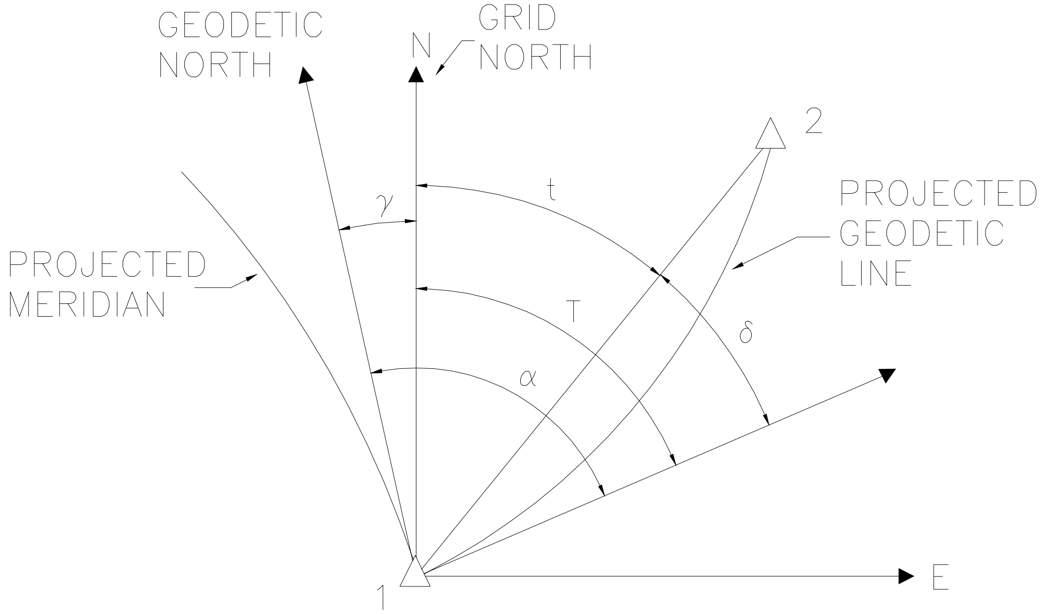
$$\begin{aligned} SF &= (Grid\ \ Factor)\ (Elevation\ \ Factor) \\ &= (0.99982734)\ (1.00003674) \\ &= 0.99986408 \end{aligned}$$

If the grid distance from the state plane coordinates was found to be 1124.234 meters, the corresponding ground distance can be found by dividing this grid distance by the combined scale factor. Thus, ground distance = grid distance/SF. This becomes 1124.387 meters. Intuitively, one should see that this value seems to be correct because it is larger than the grid distance, which is what we would expect.

4.8. Azimuths and t-T corrections on the Lambert Projection

Figure 4.9 shows the relationship between azimuths and the t-T correction. The grid azimuth, t, is defined as

Figure 4.9
Relationships between azimuths and the t-T correction.



$$t = \alpha - \gamma + \delta$$

where α = the geodetic azimuth
γ = the convergence angle or mapping angle
δ = the second-term correction or arc-to-chord correction. It is also called the t-T correction.
t = grid azimuth from north, and
T = the projected geodetic azimuth

The grid azimuth is the azimuth obtained by using the coordinates of the two end points for direction. Thus, the grid azimuth between points 1 and 2 is mainly

$$t = \tan \left[\frac{X_2 - X_1}{Y_2 - Y_1} \right]$$

This azimuth is often designated as α_g. Sometimes, the convergence angle, γ, is referred to as the difference between the geodetic and the grid azimuth. This assumption is not correct because the t-T correction is a part of this difference though the t-T correction may be insignificant for a particular project.

The arc-to-chord correction (t-T or second difference) is the difference in the observed pointing of the instrument on the ellipsoid to the pointing on the grid. This may be very small as to be insignificant, though the magnitude needs to be determined for the project before this correction is completely dismissed. Theoretically, grid azimuths are determined from grid angles and directions whereas geodetic azimuths employ observed angles and directions. From this perspective, observations need to be adjusted using the t-T correction before they can be used in grid calculations. The computation of the t-T correction is found from

$$\delta = t - T = \frac{X_2 - X_1}{2\rho_o^2 \sin 1''}\left(Y_1 - Y_o + \frac{Y_2 - Y_1}{3}\right)$$

where ρ_o is the mean radius of the ellipsoid at the mean position and Y_o is the Y-coordinate of the mean position. This formula would suffice for most surveys except for very precise surveys over the largest Lambert zones.

4.9. Transformation of Latitude and Longitude to State Plane Coordinates and Vice-Versa

Given the position of a point, compute the X, Y coordinates using the Michigan South Zone, convergence angle and grid scale factor.

ZONE DEFINING CONSTANTS

South Standard Parallel (ϕ_s) =	42° 06'
North Standard Parallel (ϕ_n) =	43° 40'
Latitude of the Grid Origin (ϕ_b) =	41° 30'
Central Meridian (λ_o) =	84° 22'
False Northing (N_b) =	0.0000m
False Easting (E_o) =	4,000,000.0000m

The location of the point is: ϕ = 43° 40' 38.61471"
λ = 85° 36' 07.05917"

COMPUTATION OF ZONE CONSTANTS

$$Q_s = \frac{1}{2}\left[\ln\frac{1 + \sin\phi_s}{1 - \sin\phi_s} - e\ln\frac{1 + e\sin\phi_s}{1 - e\sin\phi_s}\right] = 0.80702505$$

$$W_s = \left(1 - e^2\sin^2\phi_s\right)^{\frac{1}{2}} = 0.99849440$$

$$Q_n \quad \frac{1}{2}\left[\ln \frac{1 + \sin\varphi_n}{1 - \sin\varphi_n} - e \ln \frac{1 + e \sin\varphi_n}{1 - e \sin\varphi_n}\right] = 0.84421041$$

$$W_n = \left(1 - e^2 \sin^2 \varphi_n\right)^{\frac{1}{2}} = 0.99840299$$

$$Q_b = \frac{1}{2}\left[\ln \frac{1 + \sin\varphi_b}{1 - \sin\varphi_b} - e \ln \frac{1 + e \sin\varphi_b}{1 - e \sin\varphi_b}\right] = 0.79302993$$

$$\sin \varphi_o = \frac{\ln\left(\dfrac{W_n \cos \varphi_s}{W_s \cos \varphi_n}\right)}{Q_n - Q_s} = 0.68052926$$

$$K = \frac{a \cos \varphi_s \exp^{Q_s \sin\varphi_o}}{W_s \sin \varphi_o} = 12{,}061{,}671.83848$$

$$Q_o = \frac{1}{2}\left[\ln \frac{1 + \sin\varphi_o}{1 - \sin\varphi_o} - e \ln \frac{1 + e \sin\varphi_o}{1 - e \sin\varphi_o}\right] = 0.82553875$$

$$W_o = \left(1 - e^2 \sin^2 \varphi_o\right)^{\frac{1}{2}} = 0.99844865$$

$$R_b \quad \frac{K}{\exp^{Q_b \sin \varphi_o}} = 7{,}031{,}167.29066$$

$$R_o = \frac{K}{\exp^{Q_o \sin \varphi_o}} = 6{,}877{,}323.40584$$

$$k_o = \frac{W_o \; R_o \; \tan \varphi_o}{a} = 0.99990688$$

$$N_o = R_b + N_b - R_o = 153{,}843.88482$$

DIRECT CONVERSION COMPUTATION

$$Q = \frac{1}{2}\left[\ln \frac{1 + \sin\varphi}{1 - \sin\varphi} - e \ln \frac{1 + e \sin\varphi}{1 - e \sin\varphi} \right] = 0.84446832$$

$$R = \frac{K}{\exp^{Q \sin \varphi_o}} = 6{,}789{,}297.03226$$

$$\gamma = (\lambda_o - \lambda) \sin \varphi_o = 0.01467218\,rad = 0^o \; 50' \; 26.3544''$$

$$N = R_b + N_b - R \cos \gamma = 242{,}601.02077\,m$$

$$E = E_o + R \sin \gamma = 3{,}900{,}389.80163\,m$$

$$k \quad \frac{\left(1 - e^2 \sin^2 \varphi\right)^{\frac{1}{2}} \left(R \sin \varphi_o\right)}{a \cos \varphi} = 1.00000258$$

INVERSE SOLUTION

The inverse conversion computation is shown as follows:

$$R^{/} = R_b - N + N_b = 6788566.26979$$

$$E^{/} = E - E_o = -99610.1983774$$

$$\gamma = \tan^{-1}\left[\frac{E^{/}}{R2}\right] = 0^o \ 50^{/} \ 26.3537^{//}$$

$$\lambda = \lambda_o - \frac{\gamma}{\sin\varphi_0} = 85^o \ 36^{/} \ 07.05917^{//}$$

$$R = \sqrt{R^2 + E^2} = 6789297.03226$$

$$Q = \frac{\ln\left(\frac{K}{R}\right)}{\sin \varphi_o} = 0.844468321836$$

The next step involves the computation of the latitude and this is an iterative process. As an initial approximation,

$$\sin \varphi = \frac{\exp(2Q) - 1}{\exp(2Q) + 1} = 0.758961778977$$

$$f_1 = \frac{1}{2}\left[\ln\frac{1 + \sin\varphi}{1 - \sin\varphi} - e\ln\frac{1 + e\sin\varphi}{1 - e\sin\varphi}\right] - Q = -0.0046117393414$$

$$f_2 = \frac{1}{1 - \sin^2\varphi} - \frac{1}{1 - e^2\sin^2\varphi} = 1.8928935211233$$

The second approximation of the sin φ is found to be

$$\sin\ \varphi\ =\ \sin\ \varphi\ +\ \frac{-f_1}{f_2}\ =\ 0.762325072515$$

$$f_1\ =\ \frac{1}{2}\left[\ln\frac{1\ +\ \sin\varphi}{1\ -\ \sin\varphi}\ -\ e\ln\frac{1\ +\ e\sin\ \varphi}{1\ -\ e\sin\ \varphi}\right]\ -\ Q\ =\ 1.482037467992$$

$$f_2\ =\ \frac{1}{1\ -\ \sin^2\varphi}\ -\ \frac{1}{1\ -\ e^2\sin^2\varphi}\ =\ 1.905092816771$$

The third approximation of the sin φ is found to be

$$\sin\ \varphi\ =\ \sin\ \varphi\ +\ \frac{-f_1}{f_2}\ =\ 0.762314316212$$

$$f_1\ =\ \frac{1}{2}\left[\ln\frac{1\ +\ \sin\varphi}{1\ -\ \sin\varphi}\ -\ e\ln\frac{1\ +\ e\sin\ \varphi}{1\ -\ e\sin\ \varphi}\right]\ -\ Q\ =\ 0.0000000001527$$

$$f_2\ =\ \frac{1}{1\ -\ \sin^2\varphi}\ -\ \frac{1}{1\ -\ e^2\sin^2\varphi}\ =\ 1.9050535455$$

The final value for the sin φ is

$$\sin\ \varphi\ =\ \sin\ \varphi\ +\ \frac{-f_1}{f_2}\ =\ 0.76231431613$$

$$\boxed{\varphi\ =\ 43^o\ 40'\ 38.61471''}$$

$$\boxed{k\ =\ \frac{\left(1\ -\ e^2\sin^2\varphi\right)^{\frac{1}{2}}\ \left(R\sin\varphi_o\right)}{a\ \cos\varphi}\ =\ 1.0000025792}$$

4.10. MICHIGAN COORDINATE SYSTEMS (Act 9 of 1964, as amended)

Michigan has adopted the Lambert Conformal Conic Projection with three zones (see PA 9, 1964 as amended). This new system updates the legislation to reflect the change in the North American Datum of 1983. In changing to this new datum, Michigan has made a couple of significant changes in the law. First, there is no change in the datum as we had in earlier legislation. The datum surface is used in the projection. Second, the parameters of the new system are defined in meters. The legislation does allow the use of feet, but the conversion must utilize the International Foot to meter conversion. This is: 1 foot = 0.3048 meters (exact). Note that earlier legislation used the U.S. Survey Foot conversion which was defined as 1 foot = 12/39.37 meter (exact). The difference is only about 2 parts per million but with zone parameters up to tens of millions of meters this difference can be significant. The third significant change is that the recorded coordinates must contain a measure of the positional tolerance for the coordinates of that point. This is represented by the standard deviation.

The state is divided into three zones: North, Central and South. The zone boundaries follow county boundaries. The parameters for each zone are shown in Table 4.1.

Table 4.1
Parameters for the Michigan State Plane Coordinate System.

	North Zone	Central Zone	South Zone
Standard Parallel - North	47° 05'	45° 42'	43° 40'
Standard Parallel - South	45° 29'	44° 11'	42° 06'
X-Origin (meters)	8,000,000.00	6,000,000.00	4,000,000.00
Y-Origin (meters)	0.00	0.00	0.00

The Michigan State Plane Coordinate System employs a conformal projection. This means that angles, as a general rule, maintain their proper value on the projected plane. The system is also based on a design principle of keeping the distance distortion below 1:10,000. To maximize the zone width, a secant projection is used. This means that there are two lines of contact between the cone and the datum surface. By limiting the zone width to about 158 miles, the projection system can minimize the distortion in distance. This was shown in figure 4.7.

The text of the Michigan Coordinate System (Act 9 of 1964, as amended) is as follows:

> AN ACT to describe, define, and officially adopt certain systems of coordinates for designating the position of points on or near the surface of the earth within this state.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.231 Michigan coordinate system of 1927 and Michigan coordinate system of 1983 established; division of state into north zone, central zone, and south zone. [M.S.A. 13.115(1)]

Sec. 1. (1) The systems of plane coordinates which are established by the NOAA/NGS for defining and stating the positions of points on or near the surface of the earth within this state shall be known and designated as the Michigan coordinate system of 1927, or MCS 27, and the Michigan coordinate system of 1983, or MCS 83.

(2) For the purpose of the use of these systems, the state is divided into a north zone, a central zone, and a south zone.

(3) The area included in the following counties constitutes the north zone: Gogebic, Ontonagon, Houghton, Keweenaw, Baraga, Iron, Marquette, Dickinson, Menominee, Alger, Delta, Schoolcraft, Luce, Chippewa, and Mackinac.

(4) The area included in the following counties constitutes the central zone: Emmet, Cheboygan, Presque Isle, Charlevoix, Leelanau, Antrim, Otsego, Montmorency, Alpena, Benzie, Grand Traverse, Kalkaska, Crawford, Oscoda, Alcona, Manistee, Wexford, Missaukee, Roscommon, Ogemaw, Iosco, Mason, Lake, Osceola, Clare, Gladwin, and Arenac.

(5) The area included in the following counties constitutes the south zone: Oceana, Newaygo, Mecosta, Isabella, Midland, Bay, Huron, Muskegon, Montcalm, Gratiot, Saginaw, Tuscola, Sanilac, Ottawa, Kent, Ionia, Clinton, Shiawassee, Genesee, Lapeer, St. Clair, Allegan, Barry, Eaton, Ingham, Livingston, Oakland, Macomb, Van Buren, Kalamazoo, Calhoun, Jackson, Washtenaw, Wayne, Berrien, Cass, St. Joseph, Branch, Hillsdale, Lenawee, and Monroe.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.231a Definitions. [M.S.A. 13.115(1a)]

Sec. 1a. As used in this act: (a) “Coordinates” means the x and y plane rectangular coordinate values computed for a geographic position from a pair of mutually perpendicular axes. These axes are the meridian and parallel, defined in sections 5 and 5a, whose intersection defines the origin of each zone.

(b) “FGCC” means the federal geodetic control committee of the United

States department of commerce or a successor agency to the committee.

(c) “NOAA/NGS” means the national oceanic and atmospheric administration/national geodetic survey or a successor agency to the administration.

History: Add. 1988, Act 154, Imd. Eff. June 14, 1988 .

54.232 Land description. [M.S.A. 13.115(2)]

Sec. 2. (1) As established for use in the north zone, the Michigan coordinate system of 1927 or the Michigan coordinate system of 1983 shall be named, and in any land description in which it is used, shall be designated, respectively, the Michigan coordinate system of 1927, north zone, or the Michigan coordinate system of 1983, north zone.

(2) As established for use in the central zone, the Michigan coordinate system of 1927 or the Michigan coordinate system of 1983 shall be named, and in any land description in which it is used, shall be designated, respectively, the Michigan coordinate system of 1927, central zone, or the Michigan coordinate system of 1983, central zone.

(3) As established for use in the south zone, the Michigan coordinate system of 1927 or the Michigan coordinate system of 1983 shall be named, and in any land description in which it is used, shall be designated, respectively, the Michigan coordinate system of 1927, south zone, or the Michigan coordinate system of 1983, south zone.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.233 Use of coordinates. [M.S.A. 13.115(3)]

Sec. 3. The coordinates for a point on or near the earth's surface that are used to express the geographic position of that point in the appropriate zone of this system shall consist of 2 distances. Each distance shall be expressed in United States survey feet (1 foot = 12/39.37 meters) and decimals of a survey foot if using the Michigan coordinate system of 1927, or shall be expressed in meters and decimals of a meter or in international feet (1 foot = 0.3048 meter) and decimals of an international foot if using the Michigan coordinate system of 1983. One of these distances, to be known as the “x-coordinate”, shall give the position in an east and west direction; the other distance, to be known as the “y-coordinate”, shall give the position in a north and south direction. The coordinates shall depend upon and conform to values published by the NOAA/NGS for the monumented points of the North American horizontal geodetic control network, the coordinates of which monumented points were computed on the systems designated in this act.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.234 Tract extending from 1 coordinate zone into another coordinate zone; reference to boundaries. [M.S.A. 13.115(4)]

Sec. 4. If a tract of land is defined by a single description and extends from 1 into another of the coordinate zones described in section 1, the positions of all points on the tract's boundaries may be referred to either of the 2 zones. The zone which is used for reference shall be specifically named in the description.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.235 Michigan coordinate system of 1927; definition; determination of position. [M.S.A. 13.115(5)]

Sec. 5. (1) For the purposes of more precisely defining the Michigan coordinate system of 1927, the following definition by the NOAA/NGS is adopted: (a) The Michigan coordinate system of 1927, north zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitudes 45 degrees 29 minutes and 47 degrees 5 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 87 degrees zero minutes west of Greenwich and the parallel 44 degrees 47 minutes north latitude. This origin is given the coordinates: x = 2,000,000 feet and y = 0 feet.

(b) The Michigan coordinate system of 1927, central zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitude 44 degrees 11 minutes and 45 degrees 42 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 20 minutes west of Greenwich and the parallel 43 degrees 19 minutes north latitude. This origin is given the coordinates: x = 2,000,000 feet and y = 0 feet.

(c) The Michigan coordinate system of 1927, south zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitude 42 degrees 6 minutes and 43 degrees 40 minutes along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 20 minutes west of Greenwich and the parallel 41 degrees 30 minutes north latitude. This origin is given the coordinates: x = 2,000,000 feet and y = 0 feet.

(2) The position of the Michigan coordinate system of 1927 shall be as determined from horizontal geodetic control points established throughout the state in conformity with the standards of accuracy and specifications for first order or second order geodetic surveying as prepared and published by the FGCC, the geodetic positions of which control points were rigidly adjusted on the North American datum of 1927 and the coordinates of which were computed on the Michigan coordinate system of 1927.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.235a Michigan coordinate system of 1983; definition; determination of position. [M.S.A. 13.115(5a)]

Sec. 5a. (1) For purposes of more precisely defining the Michigan coordinate system of 1983, the following definition by the NOAA/NGS is adopted: (a) The Michigan coordinate system of 1983, north zone, is a Lambert conformal projection of the North American datum of 1983, having standard parallels at north latitudes 45 degrees 29 minutes and 47 degrees 5 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 87 degrees zero minutes west of Greenwich and the parallel 44 degrees 47 minutes north latitude. This origin is given the coordinates: x = 8,000,000 meters and y = 0 meters.

(b) The Michigan coordinate system of 1983, central zone, is a Lambert conformal projection of the North American datum of 1983, having standard parallels at north latitude 44 degrees 11 minutes and 45 degrees 42 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 22 minutes west of Greenwich and the parallel 43 degrees 19 minutes north latitude. This origin is given the coordinates: x = 6,000,000 meters and y = 0 meters.

(c) The Michigan coordinate system of 1983, south zone, is a Lambert conformal projection of the North American datum of 1983, having standard parallels at north latitude 42 degrees 6 minutes and 43 degrees 40 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 22 minutes west of Greenwich and the parallel 41 degrees 30 minutes north latitude. This origin is given the coordinates: x = 4,000,000 meters and y = 0 meters.

(2) The position of the Michigan coordinate system of 1983 shall be as determined from horizontal geodetic control points established throughout the state in conformity with the standards of accuracy and specifications for first order or second order geodetic surveying as prepared and published by

the FGCC, the geodetic positions of which control points were rigidly adjusted on the North American datum of 1983 and the coordinates of which were computed on the Michigan coordinate system of 1983. Standards and specifications of the FGCC in force on the date of a survey shall apply to that survey.

History: Add. 1988, Act 154, Imd. Eff. June 14, 1988 .

54.236 Presentation of coordinates for recording; contents of recording document. [M.S.A. 13.115(6)]

Sec. 6. Coordinates based on either Michigan coordinate system described in this act, purporting to define the position of a point or a land boundary corner, shall not be presented to be recorded unless the recording document contains an estimate, expressed as a standard deviation, of the positional tolerance of the coordinates being recorded. The recording document shall also contain a description of the nearest first or second order horizontal geodetic control monument from which the coordinates being recorded were determined and the method of survey for that determination. If the position of the described first or second order geodetic control monument is not published by the NOAA/NGS, the recording document shall contain a certificate signed by a land surveyor licensed under article 20 of the occupational code, Act No. 299 of the Public Acts of 1980, being sections 339.2001 to 339.2014 of the Michigan Compiled Laws, which certificate states that the described control monument and its coordinates have been established and determined in conformance with the specifications given in section 5 or 5a.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.237 Use of coordinates on map, report of survey, or other document. [M.S.A. 13.115(7)]

Sec. 7. (1) The use of the term Michigan coordinate system of 1927 on a map, report of survey, or other document shall be limited to coordinates based on the Michigan coordinate system of 1927 as defined in section 5.

(2) The use of the term Michigan coordinate system of 1983 on a map, report of survey, or other document shall be limited to coordinates based on the Michigan coordinate system of 1983 as defined in section 5a.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988 .

54.238 Describing location of survey station or land boundary corner; conflicting descriptions. [M.S.A. 13.115(8)]

Sec. 8. (1) For the purpose of describing the location of a survey station or land boundary corner in the state of Michigan, it shall be considered a complete, legal, and satisfactory description of that location to give the position of the survey station or land boundary corner by the Michigan coordinate system of 1927 or the Michigan coordinate system of 1983.

(2) If the Michigan coordinate system of 1927 or the Michigan coordinate system of 1983 is used to describe a tract of land which in the same document is also described by reference to a subdivision, line, or corner of the United States public land surveys, or to a subdivision plat duly recorded in accordance with the subdivision control act of 1967, Act No. 288 of the Public Acts of 1967, being sections 560.101 to 560.293 of the Michigan Compiled Laws, the description by coordinates shall be construed as supplemental to the basic description of the subdivision, line, or corner contained in the official plats and field notes filed of record, and in the event of a conflict, the description by reference to the subdivision, line, or corner of the United States public land surveys, or to the recorded subdivision plat, shall prevail over the description by coordinates.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.

54.239 Sole system after December 31, 1989. [M.S.A. 13.115(9)]

Sec. 9. The Michigan coordinate system of 1927 shall not be used after December 31, 1989. The Michigan coordinate system of 1983 shall be the sole system used after December 31, 1989.

History: 1964, Act 9, Eff. Aug. 28, 1964 ;--Am. 1988, Act 154, Imd. Eff. June 14, 1988.