Minnesota Department of Transportation
Office of Land Management

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Map Projections and Parameters

Last Updated on April 16, 2009

Notice of Error in Beltrami County North Zone Parameters

Conad83 was originally written in 1986 to run on the HP-310 computer system. In 1988, Conad83 was rewritten to run on IBM-compatible computers. At that time there was a transcription error, and the south parallel parameter for Beltrami County North Zone was mistakenly set one degree too far south, which results in county coordinate positional errors on the order of one to three meters. See below in the Lambert Zones table. The erroneous value persisted in the MnCon program that replaced the functionality of the Conad programs in 1997 and also appeared in some documentation of the Minnesota County Coordinate System, including this page.

This error was repaired in MnCon Version 1.9.3, released on June 7, 2001. Beginning with version 1.9.3, MnCon will include both the correct and erroneous parameters for Beltrami County North Zone. For lack of a better term, they are designated “good” and “bad” on the map projection lists and in the printed and file outputs. The uncorrected (or bad) value appears at the bottom of the lists and is included for the convenience of those who may need to convert from or to the old, erroneous county coordinates.

To summarize, any Beltrami County North Zone coordinate computed by the PC version of Conad83 or by MnCon prior to June 7, 2001 is incorrect with respect to the Minnesota County Coordinate System definition. Any coordinate projections computed from Beltrami County North Zone coordinates are also suspect and should be examined. No other counties, zones, or projections are affected.

Introduction

The following tables and examples provide the data needed to perform conversions of coordinates between map projections used in the State of Minnesota.

Required parameters, examples of usage and methods of parameter calculation are listed for all projections used in Minnesota. Since different conversion packages give the parameters different names, all known aliases have been noted.

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Click on the following links to jump to the associated topic:

NAD83 Universal Transverse Mercator (UTM)

NAD83 UTM Parameters

Zone	False Northing (meters)	False Easting (meters)	Central Meridian	Latitude of Grid Origin	Grid Scale Factor at Central Meridian	West Edge of Zone	East Edge of Zone
UTM 14	0.000	500000.000	-99 00 00	00 00 00	0.999600000000	-102 00 00	-96 00 00
UTM 15	0.000	500000.000	-93 00 00	00 00 00	0.999600000000	-96 00 00	-90 00 00
UTM 16	0.000	500000.000	-87 00 00	00 00 00	0.999600000000	-90 00 00	-84 00 00

When UTM coordinates are used in Minnesota, Zone 15 is usually extended east and west to encompass the entire state within a single zone, which may be denoted as "Zone 15E" or "Zone 15 Extended." For example, the Mn/DOT Basemap specifies "Universal Transverse Mercator (UTM) Minnesota extended Zone 15, NAD83 coordinates."

The following parameters apply to all NAD83 UTM zones:

Projection = Transverse Mercator
Spheroid = GRS 1980

UTM ARC/INFO Example

The parameters needed to convert to or from UTM Zone 15 are shown below. This can become part of a file used in ARC/INFO's PROJECT command. More detailed examples showing complete conversions are shown in the NAD83 Minnesota County Coordinate System section of this document.

```
Projection UTM
Zone 15
Datum NAD83
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
```

NAD83 Minnesota State Plane

NAD83 Minnesota State Plane Parameters

State Plane Zone	Semi-major Axis (meters)	Semi-minor Axis (meters)	Southern Standard Parallel	Northern Standard Parallel	Longitude of Origin	Latitude of Grid Origin
North	6378137.000	6356752.314	47 02 00	48 38 00	-93 06 00	46 30 00
Central	6378137.000	6356752.314	45 37 00	47 03 00	-94 15 00	45 00 00
South	6378137.000	6356752.314	43 47 00	45 13 00	-94 00 00	43 00 00

The Semi-major Axis can also be called the Equatorial Radius. It is represented by the letter *a* in equations. The Semi-minor Axis can also be called the Polar Radius. It is represented by the letter *b* in equations.

The Longitude of Origin may also be called the Central Meridian. Within various software packages, the Southern Standard Parallel may be called either Standard Parallel 1 or Standard Parallel 2, making the Northern Standard Parallel either Standard Parallel 2 or Standard Parallel 1. A process of trial and error may be necessary to determine the correct terminology.

The following constants apply for all Minnesota state plane zones:

Projection = Lambert Conformal Conic
False Northing = 100000.000 m
False Easting = 800000.000 m
Eccentricity = e = 0.08181919104283185
Flattening = f = 0.003352810681183637
Inverse Flattening = 1 / f = 298.2572221008827

State Plane ARC/INFO Example

The parameters needed to convert to or from the Minnesota North State Plane zone are shown below. This can become part of a file used in ARC/INFO's PROJECT command. More detailed examples showing complete conversions are shown in the NAD83 Minnesota County Coordinate System section of this document.

Projection STATEPLANE
Datum NAD83
Units METERS
Zone 4276
Parameters

NAD83 Minnesota County Coordinate System

Counties in the Minnesota County Coordinate System are defined using Lambert Conformal Conic, Transverse Mercator, or Oblique Mercator mapping projections. For the purpose of listing their parameters, they are separated into tables according to their mapping projections.

NAD83 Lambert Conformal Conic County Zones

NAD83 Lambert Conformal Conic Formulas

The Semi-major Axis, or Equatorial Radius, is represented by the letter *a* in equations. The Semi-minor Axis, or Polar Radius, is represented by the letter *b* in equations.

The Longitude of Origin may also be called the Central Meridian. Within various software packages, the Southern Standard Parallel may be called either Standard Parallel 1 or Standard Parallel 2, making the Northern Standard Parallel either Standard Parallel 2 or Standard Parallel 1. A process of trial and error may be necessary to determine the correct terminology.

The following constants apply for all Minnesota counties defined with the Lambert projection:

False Northing = N_0 = 30480.0610 m
False Easting = E_0 = 152400.3048 m
Eccentricity = *e* = 0.08181919104283185
Flattening = *f* = 0.003352810681183637
Inverse Flattening = 1 / *f* = 298.2572221008827

Equations for computing both the forward and inverse calculations are available in NOAA Manual NOS NGS 5 titled State Plane Coordinate System of 1983 by James E. Stem. One change must be made to make those formulas work for the Minnesota County Coordinate System Lambert Conformal Conic counties. The ellipsoid height must be added to the standard GRS80 semi-major axis.

semi-major_axis = *a* = 6378137.000 + *ellipsoid_height*

If you are using a map projection conversion from a commercial software package you will need to create a user defined ellipsoid. This generally requires the lengths of the semi-major axis and the semi-minor axis. Both are available in the table above. The way the length of the semi-minor axis of the ellipsoid was computed is as follows:

semi-minor_axis = *b* + (*ellipsoid_height* * (1 - f))
= 6356752.314 + (*ellipsoid_height* * 0.996647189318816363)

where:
ellipsoid_height = County's ellipsoid height (rarely used in commercial packages)
a = GRS80 semi-major axis (equatorial radius) = 6378137.000 m
b = GRS80 semi-minor axis (polar radius) = 6356752.314 m
f = flattening of the geodetic ellipsoid = 0.003352810681183637

NAD83 Lambert Conformal Conic County Parameters

County	Semi-major Axis (meters)	Semi-minor Axis (meters)	Southern Standard Parallel	Northern Standard Parallel	Longitude of Origin	Latitude of Grid Origin	Ellipsoid Height (meters)	Scale Factor (PPM) *
Anoka	6378418.941	6357033.310	45 04 00	45 22 00	-93 16 00	45 02 07	281.941	44.20428724
Becker	6378586.581	6357200.388	46 47 00	47 05 00	-95 41 00	46 43 04	449.581	70.48782427
Beltrami/North **	6378505.809	6357119.886	48 07 00	48 28 00	-95 01 00	48 01 12	368.809	57.82393824
Beltrami/South	6378544.823	6357158.770	47 30 00	47 55 00	-94 51 00	47 24 45	407.823	63.94077142
Benton	6378490.569	6357104.698	45 35 00	45 47 00	-94 03 00	45 33 33	353.569	55.43452579
Big Stone	6378470.757	6357084.952	45 13 00	45 32 00	-96 03 00	45 09 08	333.757	52.32828959
Blue Earth	6378403.701	6357018.121	43 56 00	44 22 00	-94 16 00	43 50 53	266.701	41.81487478
Brown	6378434.181	6357048.499	44 10 00	44 28 00	-94 44 00	44 06 29	297.181	46.59369970
Carlton	6378454.907	6357069.155	46 28 00	46 44 00	-92 41 00	46 25 02	317.907	49.84323792
Carver	6378400.653	6357015.083	44 41 00	44 54 00	-93 46 00	44 38 23	263.653	41.33699229
Cass/North	6378567.378	6357181.249	46 55 00	47 19 00	-94 13 00	46 48 13	430.378	67.47707050
Cass/South	6378546.957	6357160.896	46 16 00	46 44 00	-94 28 00	46 09 23	409.957	64.27535188
Chippewa	6378476.853	6357091.028	44 50 00	45 12 00	-95 51 00	44 45 10	339.853	53.28405458
Chisago	6378411.321	6357025.715	45 20 00	45 40 00	-93 05 00	45 17 47	274.321	43.00958101
Cook/North	6378647.541	6357261.143	47 56 00	48 10 00	-90 15 00	47 53 00	510.541	80.04547409
Cook/South	6378647.541	6357261.143	47 33 00	47 49 00	-90 15 00	47 26 20	510.541	80.04547409
Cottonwood	6378514.953	6357129.000	43 54 00	44 10 00	-94 55 00	43 50 53	377.953	59.25758572
Crow Wing	6378546.957	6357160.896	46 16 00	46 44 00	-94 28 00	46 09 23	409.957	64.27535188
Dakota	6378421.989	6357036.347	44 31 00	44 55 00	-93 19 00	44 28 19	284.989	44.68216973
Dodge	6378481.425	6357095.584	43 53 00	44 08 00	-92 55 00	43 50 02	344.425	54.00087831
Douglas	6378518.001	6357132.038	45 48 00	46 03 00	-96 03 00	45 45 32	381.001	59.73546821
Faribault	6378521.049	6357135.075	43 34 00	43 48 00	-93 57 00	43 30 00	384.049	60.21335070
Fillmore	6378464.661	6357078.876	43 33 00	43 48 00	-92 05 00	43 30 00	327.661	51.37252461
Freeborn	6378521.049	6357135.075	43 34 00	43 48 00	-93 57 00	43 30 00	384.049	60.21335070
Goodhue	6378434.181	6357048.499	44 18 00	44 40 00	-93 08 00	44 11 41	297.181	46.59369970
Grant	6378518.001	6357132.038	45 48 00	46 03 00	-96 03 00	45 45 32	381.001	59.73546821
Hennepin	6378418.941	6357033.310	44 53 00	45 08 00	-93 23 00	44 47 28	281.941	44.20428724
Houston	6378436.619	6357050.928	43 34 00	43 48 00	-91 28 00	43 30 00	299.619	46.97594298
Isanti	6378411.321	6357025.715	45 20 00	45 40 00	-93 05 00	45 17 47	274.321	43.00958101
Itasca/North	6378574.389	6357188.237	47 34 00	47 49 00	-93 44 00	47 30 00	437.389	68.57629430
Itasca/South	6378574.389	6357188.237	47 05 00	47 25 00	-93 44 00	47 01 35	437.389	68.57629430
Jackson	6378521.049	6357135.075	43 34 00	43 48 00	-93 57 00	43 30 00	384.049	60.21335070
Kanabec	6378472.281	6357086.471	45 49 00	46 20 00	-92 54 00	45 43 48	335.281	52.56723084
Kandiyohi	6378498.189	6357112.292	44 58 00	45 20 00	-94 45 00	44 53 29	361.189	56.62923202
Kittson	6378449.421	6357063.688	48 36 00	48 56 00	-96 09 00	48 32 38	312.421	48.98311215
Koochiching	6378525.621	6357139.632	48 00 00	48 37 00	-93 45 00	47 50 45	388.621	60.93017444
Lac Qui Parle	6378476.853	6357091.028	44 50 00	45 12 00	-95 51 00	44 45 10	339.853	53.28405458

Lake of the Woods/North	6378466.185	6357080.395	49 11 00	49 20 00	-94 59 00	49 09 00	329.185	51.61146586
Lake of the Woods/South	6378496.665	6357110.773	48 27 00	48 53 00	-94 53 00	48 21 58	359.665	56.39029077
Le Sueur	6378434.181	6357048.499	44 18 00	44 40 00	-93 08 00	44 11 41	297.181	46.59369970
Lincoln	6378643.579	6357257.195	44 17 00	44 37 00	-96 16 00	44 11 48	506.579	79.42428957
Lyon	6378559.758	6357173.655	44 15 00	44 35 00	-95 51 00	44 11 44	422.758	66.28236427
McLeod	6378414.369	6357028.753	44 32 00	44 55 00	-94 38 00	44 27 22	277.369	43.48746350
Mahnomen	6378586.581	6357200.388	47 12 00	47 27 00	-95 49 00	47 09 06	449.581	70.48782427
Marshall	6378441.801	6357056.093	48 14 00	48 29 00	-96 23 00	48 10 23	304.801	47.78840592
Martin	6378521.049	6357135.075	43 34 00	43 48 00	-93 57 00	43 30 00	384.049	60.21335070
Meeker	6378498.189	6357112.292	44 58 00	45 20 00	-94 45 00	44 53 29	361.189	56.62923202
Morrison	6378502.761	6357116.849	45 51 00	46 16 00	-94 12 00	45 46 26	365.761	57.34605575
Mower	6378521.049	6357135.075	43 34 00	43 48 00	-93 57 00	43 30 00	384.049	60.21335070
Murray	6378617.061	6357230.765	43 55 00	44 10 00	-95 46 00	43 50 53	480.061	75.26664918
Nicollet	6378403.701	6357018.121	43 56 00	44 22 00	-94 16 00	43 50 53	266.701	41.81487478
Nobles	6378624.681	6357238.360	43 34 00	43 48 00	-95 57 00	43 30 00	487.681	76.46135541
Norman	6378468.623	6357082.825	47 12 00	47 27 00	-96 27 00	47 09 02	331.623	51.99370913
Olmsted	6378481.425	6357095.584	43 53 00	44 08 00	-92 55 00	43 50 02	344.425	54.00087831
Ottertail	6378525.621	6357139.632	46 11 00	46 39 00	-95 43 00	46 06 23	388.621	60.93017444
Pennington	6378445.763	6357060.042	47 36 00	48 05 00	-96 22 00	47 29 56	308.763	48.40959045
Pine	6378472.281	6357086.471	45 49 00	46 20 00	-92 54 00	45 43 48	335.281	52.56723084
Pipestone	6378670.401	6357283.927	43 53 00	44 09 00	-96 15 00	43 50 57	533.401	83.62959278
Polk	6378445.763	6357060.042	47 36 00	48 05 00	-96 22 00	47 29 56	308.763	48.40959045
Pope	6378502.761	6357116.849	45 21 00	45 42 00	-95 09 00	45 16 58	365.761	57.34605575
Ramsey	6378418.941	6357033.310	44 53 00	45 08 00	-93 23 00	44 47 28	281.941	44.20428724
Red Lake	6378445.763	6357060.042	47 36 00	48 05 00	-96 22 00	47 29 56	308.763	48.40959045
Redwood	6378438.753	6357053.055	44 16 00	44 34 00	-95 14 00	44 11 41	301.753	47.31052343
Renville	6378414.369	6357028.753	44 32 00	44 55 00	-94 38 00	44 27 22	277.369	43.48746350
Rice	6378434.181	6357048.499	44 18 00	44 40 00	-93 08 00	44 11 41	297.181	46.59369970
Rock	6378624.681	6357238.360	43 34 00	43 48 00	-95 57 00	43 30 00	487.681	76.46135541
Roseau	6378449.421	6357063.688	48 36 00	48 56 00	-96 09 00	48 32 38	312.421	48.98311215
St Louis/North	6378543.909	6357157.859	47 59 00	48 32 00	-92 27 00	47 50 00	406.909	63.79746939
St Louis/ Central	6378605.783	6357219.525	47 20 00	47 45 00	-92 27 00	47 15 00	468.783	73.49842125
St Louis/South	6378540.861	6357154.821	46 47 00	47 08 00	-92 27 00	46 39 00	403.861	63.31958690
Scott	6378421.989	6357036.347	44 31 00	44 55 00	-93 19 00	44 28 19	284.989	44.68216973
Sherburne	6378443.325	6357057.612	45 02 00	45 28 00	-93 53 00	44 58 39	306.325	48.02734717
Sibley	6378414.369	6357028.753	44 32 00	44 55 00	-94 38 00	44 27 22	277.369	43.48746350
Stearns	6378502.761	6357116.849	45 21 00	45 42 00	-95 09 00	45 16 58	365.761	57.34605575
Steele	6378481.425	6357095.584	43 53 00	44 08 00	-92 55 00	43 50 02	344.425	54.00087831
Stevens	6378502.761	6357116.849	45 21 00	45 42 00	-95 09 00	45 16 58	365.761	57.34605575

Swift	6378470.757	6357084.952	45 13 00	45 32 00	-96 03 00	45 09 08	333.757	52.32828959
Todd	6378548.481	6357162.415	45 52 00	46 17 00	-94 54 00	45 46 24	411.481	64.51429312
Traverse	6378463.746	6357077.964	45 38 00	45 58 00	-96 33 00	45 35 08	326.746	51.22906579
Wabasha	6378426.561	6357040.904	44 09 00	44 25 00	-92 16 00	44 06 25	289.561	45.39899347
Wadena	6378546.957	6357160.896	46 16 00	46 44 00	-94 28 00	46 09 23	409.957	64.27535188
Waseca	6378481.425	6357095.584	43 53 00	44 08 00	-92 55 00	43 50 02	344.425	54.00087831
Watonwan	6378514.953	6357129.000	43 54 00	44 10 00	-94 55 00	43 50 53	377.953	59.25758572
Winona	6378453.688	6357067.940	43 54 00	44 08 00	-91 37 00	43 50 50	316.688	49.65211628
Wright	6378443.325	6357057.612	45 02 00	45 28 00	-93 53 00	44 58 39	306.325	48.02734717
Yellow Medicine	6378530.193	6357144.189	44 40 00	44 57 00	-95 54 00	44 32 30	393.193	61.64699818

* Entry of a scale factor in commercial software packages may be required to achieve the same results as the **MnCon** program. The scale factor is entered typically as PPM, or parts per million, but a trial-and-error process may be necessary, since some programs expect positive values, while others expect negative values. The scale factor is computed by dividing the number in the "Ellipsoid Height" column by one millionth of the GRS80 semi-major axis length, for example in Anoka County, the scale factor = 281.941/6.378137 = 44.20428724 ppm.

** The latitude of the south parallel for Beltrami County North Zone was incorrectly shown as 47 07 00. The correct value of 48 07 00 is now shown above.

NAD83 Lambert Projection ARC/INFO Example

ARC/INFO cannot convert files from a Lambert county coordinate system directly into UTM or State Plane coordinates. Instead, a two step process must be used with a conversion to latitude/longitude being the extra step. For example, to convert a coverage from Dakota County to UTM, one can run ARC/INFO's PROJECT command twice using these two projection files:

DAKOTA.PRJ
INPUT /* Dakota County to Lat/Long, metric units
Projection LAMBERT
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters 6378421.989 6357036.347
44 31 00 /* 1st standard parallel
44 55 00 /* 2nd standard parallel
-93 19 00 /* central meridian
44 28 19 /* latitude of projection's origin
152400.3048 /* false easting (meters)
30480.06096 /* false northing (meters)

OUTPUT
Projection GEOGRAPHIC

Spheroid GRS1980
Zunits NO
Units DD
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
END

UTM.PRJ
INPUT /* Lat/Long to UTM, metric units
Projection GEOGRAPHIC
Datum NAD83
Zunits NO
Units DD
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
OUTPUT
Projection UTM
Zone 15
Datum NAD83
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
END

The commands needed are:

```
PROJECT COVER SOURCECOV INTERCOV DAKOTA.PRJ
PROJECT COVER INTERCOV TARGETCOV UTM.PRJ
```

where SOURCECOV = The source (input) coverage
INTERCOV = The intermediate latitude/longitude coverage
TARGETCOV = The target (output) coverage

ARC/INFO can also convert ASCII files containing one X Y coordinate set per record separated by a space. It uses the same two projection files:

```
PROJECT FILE SOURCEFIL INTERFIL DAKOTA.PRJ
PROJECT FILE INTERFIL TARGETFIL UTM.PRJ
```

where SOURCEFIL = The source (input) ASCII file
INTERFIL = The intermediate latitude/longitude ASCII file
TARGETFIL = The target (output) ASCII file

NAD83 Transverse Mercator County Zones

NAD83 Transverse Mercator County Parameters

County	False Northing (meters)	False Easting (meters)	Central Meridian	Latitude of Grid Origin	Grid Scale Factor at Central Meridian	Ellipsoid Height (meters)
Aitkin	30481.8640	152409.3196	-93 25 57	46 09 15	1.000059152669	377.953
Clay	30481.4423	152407.2110	-96 42 00	46 37 48	1.000045317862	289.561
Clearwater	30482.2708	152411.3547	-95 22 33	47 09 06	1.000072505661	463.297
Hubbard	30482.2416	152411.2097	-94 55 14	46 48 13	1.000071553661	457.201
Lake	30482.3728	152411.8636	-91 24 33	47 04 00	1.000075844621	484.633
Mille Lacs	30481.7112	152408.5566	-93 37 14	45 33 32	1.000054146138	345.949
Washington	30481.2751	152406.3759	-92 50 00	44 44 45	1.000039836799	254.509
Wilkin	30481.5511	152407.7567	-96 31 28	46 01 18	1.000048901066	312.421

Note: St. Louis County has developed **St. Louis County Transverse Mercator Coordinate System 96** that provides a single map projection for the entire county. Map scaling error is generally limited to less than one part in 40,000. This projection is included in **MnCon**, and its parameters are provided below:

Central Meridian = 92 27 00 West
Latitude of Grid Origin = 46 37 00 North
False Northing = 1,000,000 meters
False Easting = 1,450,000 meters
Semi-Major Axis = 6,378,523 meters
Semi-Minor Axis = 6,357,138.3141403 meters
Scale Factor = 0.99998529
Inverse Flattening = 298.2752724012354

NAD83 Transverse Mercator Formulas

Equations for computing both the forward and inverse calculations are based on NOAA Manual NOS NGS 5 titled State Plane Coordinate System of 1983 by James E. Stem. When the Minnesota County Coordinate System was designed by University of Minnesota surveying professor Gerald Johnson and some graduate students, the only parameters identified for transverse Mercator counties were the central meridian, the latitude of grid origin, and an ellipsoid height. They used the same false northing (30480.0610 m) and false easting (152400.3048 m) as for the Lambert conformal conic counties. They set the grid scale factor at the central meridian to 1.000. Ellipsoid height isn't used in James Stem's manual nor in map projection conversions in commercial software packages.

In the Minnesota County Coordinate System the ellipsoid height is used in some extra steps beyond those shown in Stem's equations. These are the steps that must be added after finishing Stem's equations in the forward direction (latitude/longitude to county coordinate):

$Y_F = Y_S * ((\ R + \textit{Ellipsoid Height}\ ) / R\ )$
$X_F = X_S * ((\ R + \textit{Ellipsoid Height}\ ) / R\ )$

where: Y_F = Final northing
Y_S = Stem's northing
X_F = Final easting
X_S = Stem's easting

R = Radius of curvature in the prime vertical
Ellipsoid Height = Average ellipsoid height for county

Similarly, when doing the inverse calculations (county to latitude/longitude), these steps must be applied before starting Stem's equations:

$Y_S = Y_O / ((R + \text{Ellipsoid Height}) / R)$
$X_S = X_O / ((R + \text{Ellipsoid Height}) / R)$

where: Y_O = Original northing
X_O = Original easting

NAD83 Transverse Mercator County Zones are based on the GRS80 Ellipsoid.

Obviously, commercial software packages cannot be changed to handle this. Instead you can account for the use of the ellipsoid height by making some minor adjustments to the grid scale factor at the central meridian and the false northing and easting. The method of making these adjustments is shown below. The results from these adjusted parameters give answers that match the original method to the nearest millimeter. The adjusted parameters were listed in the above table of parameters for transverse Mercator zones.

Grid Scale Factor at Central Meridian = (R + *ellipsoid_height*) / R

where *ellipsoid_height* = County's ellipsoid height
R = Radius of curvature of the prime vertical
$= (k * a) / (1 - e^2 * \sin^2 \text{phi})^{½}$
where k = scale factor = 1.000
a = semi-major axis of the ellipsoid = 6378137 m
e = first eccentricity = 0.08181919104283185
phi = latitude at midpoint of county

False Northing and *False Easting* were computed on a trial and error basis to give the best results possible for points at the extreme edges of the county using the following procedure. First, latitudes and longitudes for the corners of each county were converted to true county coordinates to use for comparisons.

Then, using the map projection conversion from a commercial software package, a transverse Mercator projection was defined. The central meridian and latitude of origin were from the above table. The scale factor was computed as shown in the equation above. The false northing was 30480.0610 m and the false easting 152400.3048 m.

Next, the same latitudes and longitudes representing the corners of the counties were entered into the map projection conversion from the commercial package. The difference between the true county coordinates and the commercial software package's results were averaged and added to the false northing and easting. The transverse Mercator projection was redefined using the new false northing and easting. Finally, the conversions were re-run on the commercial software package. In all cases, the results were within 1 mm of the true county coordinates.

NAD83 Transverse Mercator ARC/INFO Example

ARC/INFO can convert files between a transverse Mercator county coordinate system and latitude/longitude, UTM or State Plane coordinates in a one step process. It doesn't require two steps like in the case for the Lambert conformal conic counties because the ellipsoid is not changed. For example, to convert a coverage from Washington County to UTM, one can run ARC/INFO's PROJECT command using this projection file:

```
WASH2UTM.PRJ
INPUT /* Washington County to UTM, metric units
Projection TRANSVERSE
Datum NAD83
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
1.000039836799 /* scale factor at central meridian
-92 50 00.000 /* longitude at central meridian
44 44 45.000 /* latitude of origin
152406.37590 /* false easting (meters)
30481.27510 /* false northing (meters)
OUTPUT
Projection UTM
Zone 15
Datum NAD83
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
END
```

The commands needed are:

```
PROJECT COVER SOURCECOV TARGETCOV WASH2UTM.PRJ

    where  SOURCECOV = The source (input) coverage
     TARGETCOV = The target (output) coverage
```

ARC/INFO can also convert ASCII files containing one X Y coordinate set per record separated by a space. It uses the same projection file:

```
PROJECT FILE SOURCEFIL TARGETFIL WASH2UTM.PRJ

    where  SOURCEFIL = The source (input) ASCII file
     TARGETFIL = The target (output) ASCII file
```

NAD83 Oblique Mercator County Zones

The Oblique Mercator parameters for map projection conversions in commercial software packages haven't been determined. Below are the parameters established by Professor Johnson and used by CONAD83 and MnCon.

NAD83 Oblique Mercator County Parameters

County	Latitude of Local Origin	Longitude of Local Origin	Azimuth of Positive Skew	Elevation Shift (meters)	Added Northing (meters)	Added Easting (meters)
Cook/ North Shore	46 30 00	89 19 40	62 00 00	-1693.167	-3505207.011	-6187452.376
Lake/ North Shore	46 10 00	89 58 34	46 00 00	-1697.739	-4389128.779	-4206248.413
St.Louis/NorthShore	45 45 00	90 41 30	45 00 00	-1703.835	-4358648.718	-4114808.230

The following constants apply for all Minnesota county zones defined with the Oblique Mercator projection:

False Northing = N_0 = 0.0000 m
False Easting = E_0 = 0.0000 m
Grid scale factor at the local origin = k_c = 1.0000000000000
First eccentricity = *e* = 0.08181919104283185
Computed flattening = *f* = 0.003352810681183637
Computed inverse flattening = 1 / *f* = 298.2572221008827

Oblique Mercator Formulas

Equations for computing both the forward and inverse calculations are based on NOAA Manual NOS NGS 5 titled State Plane Coordinate System of 1983 by James E. Stem. When the Minnesota County Coordinate System was designed by University of Minnesota surveying professor Gerald Johnson and some graduate students, they added some extra steps for oblique Mercator formulas to minimize the difference between ground distances and map distances. As stated above, no one has yet determined how to make them work in map projection conversions in commercial software packages.

These are the steps that must be added after finishing Stem's equations in the forward direction (latitude/longitude to county coordinate):

$$Y_F = Y_S * ((R + \textit{Elevation Shift}) / R) + N_1$$
$$X_F = X_S * ((R + \textit{Elevation Shift}) / R) + E_1$$

where: Y_F = Final northing
Y_S = Stem's northing
X_F = Final easting
X_S = Stem's easting
N_1 = Added northing
E_1 = Added easting
R = Radius of curvature
Elevation Shift = County zone elevation shift

Similarly, when doing the inverse calculations (county to latitude/longitude), these steps must be applied before starting Stem's equations:

$$Y_S = (R * (Y_O - N_1)) / (R + \textit{Elevation Shift})$$
$$X_S = (R * (X_O - E_1)) / (R + \textit{Elevation Shift})$$

where: Y_O = Original northing
X_O = Original easting

NAD83 Oblique Mercator County Zones are based on the GRS80 Ellipsoid.

NAD27 Universal Transverse Mercator

NAD27 UTM Parameters

Zone	False Northing (meters)	False Easting (meters)	Central Meridian	Latitude of Grid Origin	Grid Scale Factor at Central Meridian	West Edge of Zone	East Edge of Zone
UTM 14	0.000	500000.000	-99 00 00	00 00 00	0.999600000000	-102 00 00	-96 00 00
UTM 15	0.000	500000.000	-93 00 00	00 00 00	0.999600000000	-96 00 00	-90 00 00
UTM 16	0.000	500000.000	-87 00 00	00 00 00	0.999600000000	-90 00 00	-84 00 00

When UTM coordinates are used in Minnesota, Zone 15 is usually extended east and west to encompass the entire state within a single zone, which may be denoted as "Zone 15E" or "Zone 15 Extended." For example, the Mn/DOT Basemap specifies "Universal Transverse Mercator (UTM) Minnesota extended Zone 15, NAD83 coordinates."

The following parameters apply to all NAD27 UTM zones:

Projection = Transverse Mercator
Spheroid = Clarke 1866

UTM ARC/INFO Example

The parameters needed to convert to or from UTM Zone 15 are shown below. This can become part of a file used in ARC/INFO's PROJECT command. More detailed examples showing complete conversions are shown in the NAD83 Minnesota County Coordinate System section of this document.

Projection UTM
Zone 15
Datum NAD27
Zunits NO
Units METERS
Xshift 0.0000000000
Yshift 0.0000000000
Parameters

NAD27 Minnesota State Plane

NAD27 Minnesota State Plane Parameters

State Plane Zone	Semi-major Axis (meters)	Semi-minor Axis (meters)	Southern Standard Parallel	Northern Standard Parallel	Longitude of Origin	Latitude of Grid Origin
North	6378206.4	6356583.8	47 02 00	48 38 00	-93 06 00	46 30 00
Central	6378206.4	6356583.8	45 37 00	47 03 00	-94 15 00	45 00 00
South	6378206.4	6356583.8	43 47 00	45 13 00	-94 00 00	43 00 00

The projection definitions under NAD27 are quite similar to those under NAD83. The state plane coordinates from each datum, however, are different by about 100,000 m for Y and 190,380 m for X due to the use of different false northings and false eastings.

Another method for computing to or from NAD27 state plane coordinates used the following set of parameters . The equations that make use of them are listed in Department of Commerce publication 62-4 titled State Plane Coordinates by Automatic Data Processing by Charles N. Claire.

NAD27 State Plane Parameters for Alternate Computations

Zone	North	Central	South
L_1	2000000.00	2000000.00	2000000.00
L_2	335160.00	339300.00	338400.00
L_3	18984319.62	20006679.72	21327006.06
L_4	19471398.75	20493457.15	21874349.14
L_5	0.9999028166	0.9999220223	0.9999220448
L_6	0.7412196637	0.7233880702	0.7009277824
L_7	2861	2771	2661
L_8	24.63011	20.89747	20.12517
L_9	3.80362	3.80497	3.80662
L_{10}	5.01609	4.76197	4.46959
L_{11}	0	0	0

NAD27 State Plane ARC/INFO Example

The parameters needed to convert to or from the Minnesota North State Plane zone are shown below. This can become part of a file used in ARC/INFO's PROJECT command. More detailed examples showing complete conversions are shown in the NAD83 Minnesota County Coordinate System section of this document.

```
Projection STATEPLANE
Datum NAD27
Units METERS
Zone 4276
Parameters
```

NAD27 Minnesota Project Coordinate System

In order to achieve a coordinate system in which map distances closely matched ground distances, the Minnesota Department of Highways developed the Minnesota Project Coordinate System. In it, the State of Minnesota was divided into a grid of rectangles measuring 15 minutes of latitude by one degree of longitude. The name for each zone was XX-YYYY where XX is the line of longitude marking the east edge of the rectangle and YYYY is the line of latitude forming the south edge of the rectangle. For example zone 93-4445 is bounded by 94 degrees longitude to the west, 45 degrees latitude to the north, 93 degrees longitude to the east and 44 degrees, 45 minutes latitude to the south. Parameters consisting of a combined factor, X constant and Y constant were established for each project coordinate system zone that was defined by one of these rectangles. More information about this was written by Robert B. Roscoe, P.E., in a paper titled ***Project Coordinate System--A Ground Coordinate System for Surveyors and Engineers.***

NAD27 Minnesota Project Coordinate System Formulas

State plane coordinates must always be computed as an intermediate step between the project coordinate system and latitude/longitude and between the project coordinate system and Universal Transverse Mercator. The equations for converting project coordinate system coordinates to state plane are as follows:

$$Y_s = CF * (Y_p + Y_c)$$
$$X_s = CF * (X_p + X_c)$$

where Y_s = State Plane Y Coordinate
Y_p = Project Y Coordinate
Y_c = Y Constant
X_s = State Plane X Coordinate
X_p = Project X Coordinate
X_c = X Constant
CF = Combined Factor

To convert state plane coordinates to project coordinate system coordinates, these equations are used:

$$Y_p = (Y_s / CF) - Y_c$$
$$X_p = (X_s / CF) - X_c$$

NAD27 Project Zones Lying in the North State Plane

NAD27 North State Plane Project Zone Parameters

Project Zone	Y Constant	X Constant	Combined Factor
96-4845	800000	600000	1.0000272
96-4830	709000	600000	0.9999524
96-4815	618000	600000	0.9999016
96-4800	527000	600000	0.9998700
96-4745	435000	600000	0.9998568
96-4730	344000	600000	0.9998639
96-4715	253000	600000	0.9998893
96-4700	162000	600000	0.9999335
95-4845	800000	800000	1.0000177
95-4830	709000	800000	0.9999477
95-4815	618000	800000	0.9998969
95-4800	527000	800000	0.9998605
95-4745	435000	800000	0.9998521
95-4730	344000	800000	0.9998449
95-4715	253000	800000	0.9998703
95-4700	162000	800000	0.9999097
94-4900	893000	1100000	1.0001119
94-4845	800000	1100000	1.0000177
94-4830	709000	1100000	0.9999477
94-4815	618000	1100000	0.9998969
94-4800	527000	1100000	0.9998605
94-4745	435000	1100000	0.9998425
94-4730	344000	1100000	0.9998449
94-4715	253000	1100000	0.9998703
93-4830	709000	1300000	0.9999477
93-4815	618000	1300000	0.9998873
93-4800	527000	1300000	0.9998605
93-4745	435000	1300000	0.9998425
93-4730	344000	1300000	0.9998449
93-4715	253000	1300000	0.9998655
93-4700	162000	1300000	0.9999097
93-4645	162000	1300000	0.9999019
92-4830	709000	1600000	0.9999381
92-4815	618000	1600000	0.9998873
92-4800	527000	1600000	0.9998510

92-4745	435000	1600000	0.9998378
92-4730	344000	1600000	0.9998401
92-4715	253000	1600000	0.9998655
92-4700	162000	1600000	0.9999145
92-4645	162000	1600000	0.9999019
92-4630	162000	1600000	0.9998845
91-4800	527000	1800000	0.9998510
91-4745	435000	1800000	0.9998283
91-4730	344000	1800000	0.9998305
91-4715	253000	1800000	0.9998655
91-4700	162000	1800000	0.9999097
91-4645	162000	1800000	0.9998971
90-4800	527000	2100000	0.9998462
90-4745	435000	2100000	0.9998330
90-4730	344000	2100000	0.9998401

NAD27 Project Zones Lying in the Central State Plane

NAD27 Central State Plane Project Zone Parameters

Project Zone	Y Constant	X Constant	Combined Factor
96-4700	618000	600000	0.9999335
96-4645	618000	600000	0.9999209
96-4630	527000	600000	0.9998845
96-4615	435000	600000	0.9998666
96-4600	344000	600000	0.9998783
96-4545	253000	600000	0.9999037
96-4530	162000	600000	0.9999479
96-4515	162000	600000	0.9999881
95-4715	618000	800000	0.9998703
95-4700	618000	800000	0.9999097
95-4645	618000	800000	0.9998924
95-4630	527000	800000	0.9998702
95-4615	435000	800000	0.9998571
95-4600	344000	800000	0.9998640
95-4545	253000	800000	0.9998941
95-4530	162000	800000	0.9999431
95-4515	162000	800000	0.9999833
94-4715	618000	1100000	0.9998703
94-4700	618000	1100000	0.9999097
94-4645	618000	1100000	0.9999019
94-4630	527000	1100000	0.9998702
94-4615	435000	1100000	0.9998618
94-4600	344000	1100000	0.9998735
94-4545	253000	1100000	0.9998989
94-4530	162000	1100000	0.9999431
94-4515	162000	1100000	0.9999833
93-4715	618000	1300000	0.9998655
93-4700	618000	1300000	0.9999097
93-4645	618000	1300000	0.9999019
93-4630	527000	1300000	0.9998749
93-4615	435000	1300000	0.9993618
93-4600	344000	1300000	0.9998735
93-4545	253000	1300000	0.9998989
93-4530	162000	1300000	0.9999526

93-4515	162000	1300000	0.9999928
92-4645	618000	1600000	0.9999019
92-4630	527000	1600000	0.9998845
92-4615	435000	1600000	0.9998666
92-4600	344000	1600000	0.9998783
92-4545	253000	1600000	0.9999132
92-4530	162000	1600000	0.9999574
92-4515	162000	1600000	0.9999928

NAD27 Project Zones Lying in the South State Plane

NAD27 South State Plane Project Zone Parameters

Project Zone	Y Constant	X Constant	Combined Factor
96-4530	800000	600000	0.9999479
96-4515	800000	600000	0.9999881
96-4500	709000	600000	0.9999357
96-4445	618000	600000	0.9998929
96-4430	527000	600000	0.9998598
96-4415	435000	600000	0.9998503
96-4400	344000	600000	0.9998595
96-4345	253000	600000	0.9999072
96-4330	162000	600000	0.9999686
95-4515	800000	800000	0.9999881
95-4500	709000	800000	0.9999310
95-4445	618000	800000	0.9998976
95-4430	527000	800000	0.9998741
95-4415	435000	800000	0.9998693
95-4400	344000	800000	0.9998768
95-4345	253000	800000	0.9999072
95-4330	162000	800000	0.9999686
94-4530	800000	1100000	0.9999431
94-4515	800000	1100000	0.9999833
94-4500	709000	1100000	0.9999310
94-4445	618000	1100000	0.9998976
94-4430	527000	1100000	0.9998788
94-4415	435000	1100000	0.9998788
94-4400	344000	1100000	0.9998978
94-4345	253000	1100000	0.9999262
94-4330	162000	1100000	0.9999829
93-4530	800000	1300000	0.9999526
93-4515	800000	1300000	0.9999928
93-4500	709000	1300000	0.9999357
93-4445	618000	1300000	0.9998976
93-4430	527000	1300000	0.9998836
93-4415	435000	1300000	0.9998788
93-4400	344000	1300000	0.9998978
93-4345	253000	1300000	0.9999262

93-4330	162000	1300000	0.9999829
92-4515	800000	1600000	0.9999928
92-4500	709000	1600000	0.9999357
92-4445	618000	1600000	0.9998976
92-4430	527000	1600000	0.9998836
92-4415	435000	1600000	0.9998788
92-4400	344000	1600000	0.9998978
92-4345	253000	1600000	0.9999262
92-4330	162000	1600000	0.9999829
91-4415	435000	1800000	0.9998788
91-4400	344000	1800000	0.9998978
91-4345	253000	1800000	0.9999357
91-4330	162000	1800000	0.9999924

Other Minnesota Project Coordinate Zones

Project Zones Lying Along North Shore of Lake Superior

There are five Project Coordinate System zones that lie along the north shore of Lake Superior. The portions of these zones that have a National Geodetic Vertical Datum of 1929 elevation below 1200 feet have been given different parameters than the rest of those zones to provide better results.

NAD27 North Shore Project Zone Parameters

Project Zone	Y Constant	X Constant	Combined Factor
91-4715	253000	1800000	0.9998941
91-4700	162000	1800000	0.9999383
91-4645	162000	2100000	0.9999266
90-4745	435000	2100000	0.9998616
90-4730	344000	2100000	0.9998687

NAD27 Project Coordinate System -- Modified for Counties

Some counties have defined project zones that cover different, often larger, areas than the original rectangles. This enabled all county mapping to be done in one or two or three zones rather than dealing with many of the rectangular one degree by 15 minute zones. The formulas are identical to those used in the Minnesota Project Coordinate System. The parameters for known project zones created for counties are as follows:

NAD27 County Project Zone Parameters

County Project Zone	Y Constant	X Constant	Combined Factor
Anoka, North	700000	1300000	1.0000073
Anoka, Central	700000	1300000	0.9999644
Anoka, South	700000	1300000	0.9999321
Carver	300000	1000000	0.9998906
Dakota	527000	1300000	0.9998836
Hennepin	500000	1300000	0.9999129
Ramsey	500000	1300000	0.9999129
Scott	527000	1300000	0.9998836
Washington, North	709000	1600000	0.9999490
Washington, Central	618000	1600000	0.9999490
Washington, South	618000	1600000	0.9999064

Conversions Between Datums

Converting data between the North American Datum of 1927 and the North American Datum of 1983 is not a simple task, since no direct mathematic relationship exists between them. There are, however, several ways to convert data. The appropriate method for any situation depends mostly on accuracy requirements. If a high degree of accuracy is required, additional information is necessary. For example, the coordinates of some points in a data set from both datums will be needed. In addition, best results can be achieved if surveying measurements between data set points are available.

The most accurate way to convert data from one datum to the other is not always feasible. It is the case where coordinates are known from both datums for one or more control points that are part of the data set and measurements from those control points(s) are available to all the other points in the data set. In this situation, the way to convert the data set to the other datum is by starting with the other datum's coordinates on the control point(s) and recomputing the coordinates of all the other points based on the measurements from the control points. This method will definitely provide data that is sufficiently accurate for engineering or surveying uses.

The next most accurate method is for the case where coordinates are known from both datums for three or more points in a data set, but measurements are not available. In this situation, a transformation algorithm can be used to compute the relationship between the two datums and apply it to the other points in the data set. This method may provide data that is sufficiently accurate for engineering or surveying uses, depending on the geographic extent of the data set being converted and the statistical results of the transformation.

If accuracy is not as important, there are several tools that can be used to convert between datums. The most famous is the National Geodetic Survey's NADCON, which can convert between NAD27 latitude/longitude and NAD83 latitude/longitude. Mn/DOT's **MNCON** program contains the NADCON functionality. The U.S. Army Corps of Engineers has a similar program called CORPSCON that extends the ability to state plane and Universal Transverse Mercator coordinates. Both of these programs are available from the National Geodetic Survey. ARC/INFO includes the NADCON algorithm in its PROJECT command, which can compute conversions within or between datums.

Datum Conversion ARC/INFO Example
ARC/INFO can convert between datums. In this example, a coverage in NAD27 latitude/longitude will be converted to a coverage in NAD83 latitude/longitude.

DATUM.PRJ
INPUT /* NAD27 Lat/Long to NAD83 Lat/Long
Projection GEOGRAPHIC
Datum NAD27
Zunits NO
Units DD
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
OUTPUT
Projection GEOGRAPHIC
Datum NAD83
Zunits NO
Units DD
Xshift 0.0000000000
Yshift 0.0000000000
Parameters
END

The command needed is:

PROJECT COVER SOURCECOV TARGETCOV DATUM.PRJ

where SOURCECOV = The source (input) coverage
TARGETCOV = The target (output) coverage