Location

THE ALASKA COORDINATE SYSTEM NAD-27 AND NAD-83

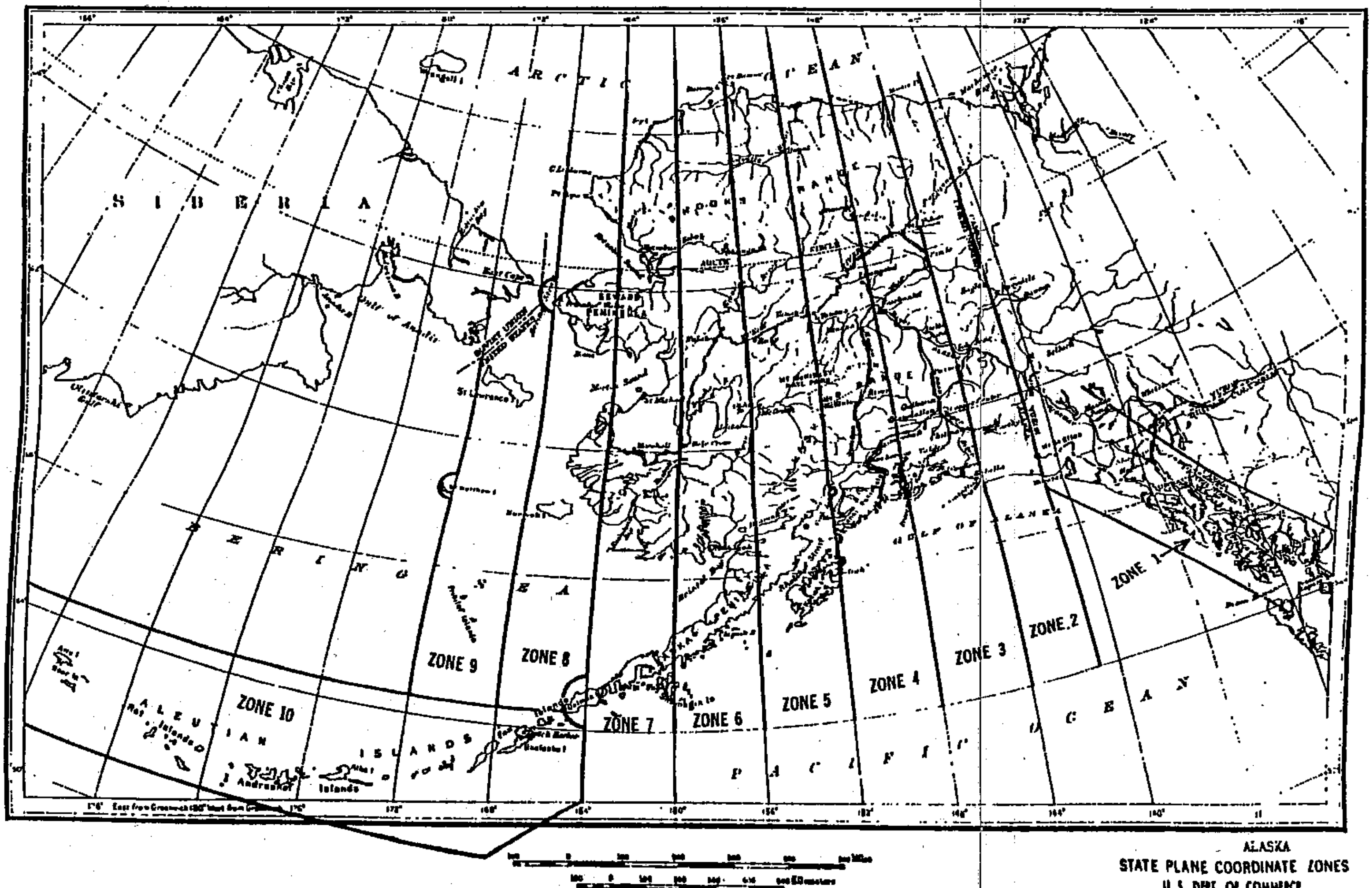
A SHORT COURSE
SPONSORED BY

ALASKA SOCIETY OF
PROFESSIONAL LAND SURVEYORS

AMERICAN CONGRESS ON
SURVEYING & MAPPING

by

William W. Mendenhall, L.S., P.E.



ALASKA
STATE PLANE COORDINATE ZONES
U. S. DEPT. OF COMMERCE
COAST AND GEODETIC SURVEY
H. Arnold Karo, Director

Figure 1.

INTRODUCTION

There are ten State Plane Coordinate Zones in Alaska. Zone 1 is an Oblique Mercator projection, covering Southeast Alaska. Zone 10 is a Lambert Conformal Conic projection covering the Aleutian Islands. For this short course, these two zones will not be covered. Only the eight zones (Zones 2-9) will be covered.

ZONES 2-9

These zones are Transverse Mercator projections. With a few exceptions, these zones are 4 degrees of longitude wide.

DEFINITION OF ZONES 2-9

Zone	Limits of Zone W. Longitude	Central Meridian W. Longitude	Central Meridian Constant
2	141 - 144	142	500,000
3	144 - 148	146	500,000
4	148 - 152	150	500,000
5	152 - 156	154	500,000
6	156 - 160	158	500,000
7	160 - 164	162	700,000
8	164 - 168	166	500,000
9	168 - 172	170	600,000

BASIS OF COORDINATES

Zone	Latitude,	Longitude	X	Y
2	54	142	500,000	0
3	54	146	500,000	0
4	54	150	500,000	0
5	54	154	500,000	0
6	54	158	500,000	0
7	54	162	700,000	0
8	54	166	500,000	0
9	54	170	600,000	0

For all zones 2-9, the scale factor at the Central Meridian is 0.9999000. Scale factors are always expressed to 7 decimal places, such as 0.9999207 or 1.0000042.

SHAPE OF THE SPHEROID

Whereas the NAD-83 system uses meters, and the WGS84 Spheroid, the old NAD-27 system uses feet and the Clarke Spheroid of 1866. Also, the NAD-83 system uses coordinates of East and North, the NAD-27 system uses coordinates of X and Y.

REDUCTION TO THE SPHEROID

Technically, all horizontal measured distances should be reduced to a mathematical spheroid. This is extremely hard for a surveyor to do, since the "height of the geoid" is just about impossible to obtain. The actual sea level surface may be up to about 40 feet above or below the mathematical surface. Therefore, for all practical purposes, we shall use the term "reduction to sea level."

The Earth is really in a somewhat ellipsoidal shape, and it is really not correct to use the term "Radius of the Earth." But for our purpose, no significant error will be introduced if we use this term. Most "canned" surveying programs by Hewlett-Packard, etc. use a radius value of 20,906,000 feet, which is a good approximate value for the "lower 48" states. For work in Alaska, we shall use a value of approximately 20,965,000 feet.

$$L_0 = L \frac{R}{R + h} \qquad R = 20,965,000$$

PROBLEM

A line AB has a taped horizontal length of 1254.87 feet. This line is at elevation 2450 feet. What is the "sea level" length of this line?

Line MN has an EDM horizontal length of 7,265.94 feet. The elevation of this line is at 1823.75 feet. What is the "sea level" length of this line?

SCALE FACTORS

The actual surface of the Earth is almost spherical, but to use a "plane" coordinate system for our surveys, we must use a term called the "scale factor." Using this factor with the "geodetic" length, we obtain the "grid" length" (the length to use for all of the state plane coordinate computations.)

Grid Length = Geodetic (sea level) Length x Scale Factor

or Grid L. = Geod. L. x S.F.

The scale factors in actual use are usually between about 0.9999 and 1.0001. In other words, grid lengths could differ from sea level lengths by a maximum (usually) of one part in 10,000. Back when state plane coordinate systems were first set up, surveyors measured to about one part in 3000, and scale factors were usually ignored. Now, with EDM, a measured accuracy of one part in 3000 would be laughed at, and thus, for today's work, scale factors must be used. For state plane work, the scale factors are usually given to seven decimal places, such as 0.9999206 or 1.0000047.

X′

Before getting into scale factors, the term X′ (pronounced X prime) should be defined.

X′ = X - the central meridian constant
X′ = X - 500,000 for all zones except zone 7 and zone 9
X′ = X - 700,000 for zone 7
X′ = X - 600,000 for zone 9

PROBLEM

A point is at Zone 4   X = 457,200.50   Y = 4,123,654.48
What is the value of X′ at this point?

Another point is at Zone 7, X = 720,456.90   Y = 2,765,496.54
What is the value of X′ at this point?

Note that the X′ values may be either + or - . Although the sign is important for many purposes, it may be ignored when obtaining the scale factor.

SCALE FACTORS (AGAIN)

For short lines, the "grid length" (the distance to use with the state plane coordinate system) is obtained by the relation:

Grid L. = Geodetic L. x Scale Factor
Grid L. = Geod. L. x S.F.

There are two ways to get the scale factor.

1. Find the X′ value at the midpoint. Use the table on the next page to find the scale factor. Interpolate if necessary. Note that the "absolute value" of X′ is used with these tables. This main part of the table is based on Y values being near 3,000,000 feet, or near the mid latitude of the main portion of Alaska. If the Y values differ from 3,000,000 feet, apply the seventh decimal place correction at the bottom of the page.

2. Use this formula:

$$S.F. = 0.9999 + [\ 1.13959 \times 10^{-15} - 5.54 \times 10^{-25}\ Y\ ]\ (X')^{2}$$

This formula will work over the entire Alaska Zone 2-9 system. If you know the general value of Y where you are working, you can simplify this formula,

For the Anchorage area, where Y is about 2,500,000, the formula

Scale Factors

x′ (feet)	Scale Factor	x′ (feet)	Scale Factor	x′ (feet)	Scale Factor
0	.9999000	250,000	.9999711	500,000	1.0001844
10,000	9001	260,000	9769	510,000	1959
20,000	9005	270,000	9829	520,000	2076
30,000	9010	280,000	9892	530,000	2196
40,000	9018	290,000	.9999957	540,000	2317
50,000	.9999028	300,000	1.0000024	550,000	1.0002441
60,000	9041	310,000	0093	560,000	2568
70,000	9056	320,000	0165	570,000	2696
80,000	9073	330,000	0239	580,000	2827
90,000	9092	340,000	0315	590,000	2960
100,000	.9999114	350,000	1.0000394	600,000	1.0003096
110,000	9138	360,000	0474	610,000	3233
120,000	9164	370,000	0557	620,000	3373
130,000	9192	380,000	0643	630,000	3515
140,000	9223	390,000	0730	640,000	3660
150,000	.9999256	400,000	1.0000820	650,000	1.0003807
160,000	9291	410,000	0912	660,000	3956
170,000	9329	420,000	1007	670,000	4107
180,000	9369	430,000	1103	680,000	4261
190,000	9411	440,000	1202	690,000	4417
200,000	.9999455	450,000	1.0001304	700,000	1.0004575
210,000	9502	460,000	1407		
220,000	9551	470,000	1513		
230,000	9602	480,000	1621		
240,000	9655	490,000	1731		
250,000	.9999711	500,000	1.0001844		

Correction to Scale Factor (7th Decimal Place)

y \ x′	0	100,000	200,000	300,000	400,000	500,000	600,000	700,000
7,000,000	0	0	−1	−2	−3	−5	−8	−10
6,000,000	0	0	−1	−2	−2	−4	−6	−8
5,000,000	0	0	0	−1	−2	−3	−4	−6
4,000,000	0	0	0	−1	−1	−1	−3	−3
3,000,000	0	0	0	0	0	0	0	0
2,000,000	0	0	0	0	+1	+2	+2	+3
1,000,000	0	0	+1	+1	+2	+3	+4	+6
0	0	0	+1	+2	+3	+5	+7	+9

x

Scale-Factor Correction for a Line

The scale factor interpolated for the mean x′ of the ends of a line and corrected by the following table will give a mean scale factor for the line correct to about one in the seventh decimal place.

Δx (feet)	Correction (plus) (units of 7th decimal place)	Δx (feet)	Correction (plus) (units of 7th decimal place)
10,000	0	210,000	42
20,000	0	220,000	46
30,000	1	230,000	50
40,000	2	240,000	55
50,000	2	250,000	59
60,000	3	260,000	64
70,000	5	270,000	69
80,000	6	280,000	74
90,000	8	290,000	80
100,000	10	300,000	86
110,000	11	310,000	91
120,000	14	320,000	97
130,000	16	330,000	103
140,000	19	340,000	110
150,000	21	350,000	116
160,000	24		
170,000	27		
180,000	31		
190,000	34		
200,000	38		

Definition of Zones 2-9

Zone	Central Meridian Longitude	Constant (feet)
2	142° W	500 000.00
3	146°	500 000.00
4	150°	500 000.00
5	154°	500 000.00
6	158°	500 000.00
7	162°	700 000.00
8	166°	500 000.00
9	170°	600 000.00

The above quantities are needed to determine $\Delta\lambda$ and x in equations (1) and (2).

becomes:

$$S.F. = 0.9999 + 1.13820 \times 10^{-15} \cdot (X')^2$$

For the Fairbanks area, where Y is about 4,000,000, use

$$S.F. = 0.9999 + 1.13737 \times 10^{-15} (X')^2$$

EXAMPLES

If X' = 200,000 near Anchorage

S.F. = 0.9999 + 0.0000455 = 0.9999455

If X' = 200,000 near Fairbanks

S.F. = 0.9999 + 0.0000455 = 0.9999455

This shows that the formula is not very sensitive to Y values.

PROBLEM

A point is at Zone 3 X = 275,140 Y = 3,970,560. What is the scale factor at this point?

A point is at Zone 7 X = 450,600 Y = 1,020,500. What is the scale factor at this point?

Use both the tables and the formula for these problems.

A short line has a sea level length of 1456.84 feet. The scale factor is 0.9999215. What is the grid length of this line?

COMBINED FACTORS

Suppose you are working on an airport project whose center is at Zone 3 X = 480,000 Y = 4,100,000 and the general elevation is about 2080 feet. If you were to measure a line having a horizontal length of 956.47 feet, you would have to reduce this to a geodetic (sea level) length of:

$$L_0 = L \frac{R}{R + h} = 956.47 \frac{20{,}965{,}000}{20{,}965{,}000+2080} = 956.47 \times 0.9999008$$

This ratio 0.9999008 is called the "sea level reduction factor" and this same ratio would apply to all lines measured at the same elevation of 2080 feet.

The state plane scale factor (S.F.) at this point is 0.9999005.

"Combined" factor = sea level factor x scale factor

Combined factor = 0.9999008 x 0.9999005 = 0.9998013

This means that for this airport project, all horizontal lengths can be multiplied by 0.9998013 to get the "grid" length. Thus, the line which was measured as 956.47 feet long will be, for our purposes:

956.47 x 0.9998013 = 956.28 grid feet

Similarly, for the same project, a line measured as 1878.87 feet long will have a grid length of:

1878.87 x 0.9998013 = 1878.50 feet

STATE PLANE COORDINATES ON SHORT LINES

Estimate where the approximate mid-point of a line is, then determine the scale factor there. Take the geodetic (sea-level) length and multiply it by the scale factor to get the "grid" length. Then using the usual methods, find the new grid coordinates at the end of the line.

EXAMPLE

Point Wolf is at Zone 4, X = 515,468.67 Y = 4,100,543.26. Line Wolf-Fox has a grid (state plane) azimuth from north of 98° 27′ 30" and a geodetic (sea level) length of 2875.42 feet. What are the state plane coordinates of point Fox?

Go half the distance (to the midpoint) of about 1438 feet, on an azimuth of 98° 27′ 30" and the approximate coordinates of the mid-point are:

X = 515,469 + 1438 sin 98° 27′ 30" = 516,891

Y = 4,100,543 + 1438 cos 98° 27′ 30" = 4,100,331

Using either the formula or the scale factor tables, you will find that the scale factor at this midpoint is 0.9999004

Grid L. = Geod. L x S.F. = 2875.42 x 0.9999004 = 2875.13

Knowing the original coordinates (X=515,468.67 Y=4,100,543.26), the grid azimuth (98° 27′ 30") and now the grid length (2875.13) we can compute the final end (Fox) position to be at

X = 518,312.53 Y = 4,100,120.36

PROBLEM

Point King is at Zone 3 X = 285,600.50 Y = 3,998,400.60. The grid azimuth from King to Queen is 278° 20′ 15" and the geodetic length King-Queen is 14,750.20 feet long. What are the Zone 3 coordinates of Queen?

SCALE FACTORS FOR LONG LINES

If a line is over 25,000 feet long in east-west extent, then there is a problem, since the scale factor keeps changing all along the line, and you can no longer simply find the scale factor at the midpoint. You already should have the coordinates at the beginning of the line.

Next, get an approximate location of the midpoint of the line, and also of the far end of the line. From here, you can proceed in one of three ways:

1. Simpson's Rule method. Find the scale factors at the beginning, mid-point, and far end of the line. Find the "overall" scale factor for the line by Simpson's Rule:

$$\text{S.F. (line)} = \frac{\text{S.F. (beg)} + 4 \times \text{S.F. (mid)} + \text{S.F. (end)}}{6}$$

2. Scale factor tables. Find the S.F. at the mid-point of the line, using the scale factor tables. Now find the absolute value of the "change" in the X-coordinates from the beginning to the end of the line. Call this "delta X." Use the "Scale Factor Correction for a Line" tables to find the seventh decimal place correction, which always is added to the scale factor at the mid-point of the line. The result will be the scale factor you should apply to the whole line. Grid L. = Geod. L. x S.F.

3. This is really the same as method 2, except that you will use formulas. You know the approximate coordinates of the mid-point of the line, and also the difference in X coordinates from the beginning to the and of the line.

Find the S.F. at the midpoint by the formula:

$$\text{S.F.} = 0.9999 + [\,1.13959 \times 10^{-15} - 5.54 \times 10^{-25}\ Y\,]\ (X')^2$$

Now find the difference in X-coordinates from the beginning of the line to the approximate end of the line. Call this ΔX or delta X. Next use a Scale Factor Correction Formula:

$$\text{Scale Factor Correction} = +9.51 \times 10^{-17}\ (\Delta X)^2$$

Example: If the east-west extent of a line is 80,000 feet, then the scale factor correction is

$$\text{Corr.} = +9.51 \times 10^{-17}\ (80{,}000)^2 = +\ 0.0000006$$

Therefore, if the scale factor at the midpoint had been 0.9999456 the overall scale factor to use for the whole line would be:

$$0.9999456 + 0.0000006 = 0.9999462$$

PROBLEM

Point Hotel is at Zone 4 X = 560,234.58 Y = 2,500,765.40 A line from Hotel to Sierra has a grid azimuth of 53° 07′ 48.37" and has a geodetic length of exactly 100,000.00 feet. What are the Zone 4 coordinates of Sierra? It is suggested that this problem be worked in two ways: Simpson's Rule and the "delta X" method, either by tables or formulas.

MAPPING ANGLE OR "DELTA ALPHA" $\Delta\alpha$

Just as a surveyor can have true directions and magnetic directions, it is possible to have true azimuths and "grid" azimuths. In general, this difference is called the "mapping angle" or for Zones 2-9, the "delta alpha" angle. (Alpha is a common term for azimuth.)

True Azimuth = Grid Azimuth + Delta Alpha

or True Azimuth = Grid Azimuth + Mapping Angle

For all Transverse Mercator zones (such as Alaska Zones 2-9) the mapping angle is always positive (+) when you are east of the central meridian and negative (-) when you are west of the central meridian.

Assuming you are in the Western Hemisphere (Zones 2-9 are) if you should happen to know the latitude and longitude of a point, the mapping angle can be found by:

tan (mapping angle) = sin (latitude) x tan (long. of central meridian - longitude of the point)

EXAMPLE

Near Fairbanks Long. 64° 50′ N., Long. 147° 45′ W. you are in Zone 3, whose central meridian longtude is 146 W. What is the mapping angle?

$$\tan(\text{map. ang}) = \sin 64° 50' \times \tan(146° - 147° 45')$$

$$\text{or} \quad \tan \Delta\alpha = \sin 64° 50' \times \tan(-1° 45')$$

$$\text{mapping angle} = \Delta\alpha = -1° 35' 02''$$

So a line with a grid (state plane) azimuth of 227° 46′ has a true azimuth of 227° 46′ - 1° 35′ = 226° 11′.

PROBLEM

At Lat. 63° 38′ 20" N. Long. 147° 58′ 10" W. What is the mapping angle for Zone 3? This point is only about a mile from the Zone 4 border. What is the mapping angle for Zone 4?

A short section of highway has a Zone 3 grid azimuth of 260° 42′ 10". What is the true azimuth of this section of road? What is the Zone 4 grid azimuth of this road?

MAPPING ANGLES USING COORDINATES

Most times, a surveyor working on a project does not know what the latitudes and longitudes of survey points are. If fact usually only the coordinates are known. It is still possible to compute mapping angles. If you know the X coordinate of a point, you can easily determine X′ or X-prime.

$$X' = X \text{ coordinate} - \text{central meridian constant (usually 500,000)}$$

$$\tan(\Delta\alpha)_{Deg} = \sin(k_1 \times X')_{Rad} \times \tan(k_2 + k_3 \times Y)_{Rad}$$

where the k values represent constants

$$k_1 = 4.787372 \times 10^{-8}$$

$$k_2 = 0.940561$$

$$k_3 = 4.780721 \times 10^{-8}$$

Note: this formula gives angles correct within 0.3" for longitudes within 2° of the central meridian

The "rad" subscripts mean that your calculator must be in the radian mode before you hit the sine or tangent key. Normally you would like to get the mapping angle in decimal degrees, so make sure the calculator is in degree mode before hitting the arc tan key. You can then change the decimal degrees to D.MS.

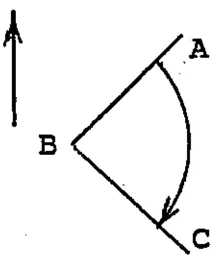
PROBLEM

A survey point, Caribou, is at Zone 3 X = 680,000.00 and Y = 4,000,000.00. What is the mapping angle, delta alpha?

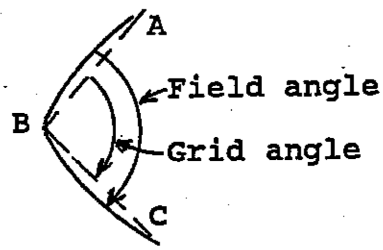
CONVERSION OF FIELD ANGLES TO GRID ANGLES

If you were to set a theodolite up over point B, backsight on point A, and turn a clockwise angle to sight on point C, you are turning a field angle (also called a geodetic angle.) The line between you and point A is obviously a straight line, and the line between you and point C is also a straight line.

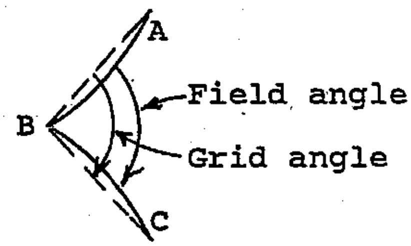
You are turning the angle, in the field, on a curved surface (the spheroid.) If you were to plot a series of points lying on lines BA and also BC on the state plane coordinate grid system you would find that on the grid, line BA had some curvature, and line BC also would have some curvature. In fact, any line, except lines running due east-west, will have some curvature. The amount and direction of the curvature depends on the location of the lines in the coordinate system. See sketch below.



Angle ABC as turnedin the field



Solid lines represent lines BA and BC as plotted on the grid system, if they are <u>west</u> of the central meridian (in a transverse Mercator zone)



Solid lines represent lines BA and BC as plotted on the grid system, if they are <u>east</u> of the central meridian (in a transverse Mercator zone)

Let us take a line, like BA, and for this example, assume that it is on the west side of the central meridian.

The actual path of line BA, as transformed onto the grid system, is plotted as a solid line. The dashed line is merely a straight line on the grid system. At point B (where the instrument is, and where the angle was turned) there is a small angular difference between the "field" line BA and the straight "grid" line BA. This is called the arc-to-chord correction. The British call this the t-T correction, and the Americans call it the T-t correction. Some authors call it "J" which is the term we will use.

For any line, the value of J depends on the location of the line in the coordinate system. U.S.C.&G.S. Publication 65-1, Part 50 (for Alaska Zones 2-9) gives the correction as being:

$$J'' = \frac{(Y_2 - Y_1)\ (X_2' + 2\ X_1')}{1.276 \times 10^{10}} \qquad J^\circ = \frac{(Y_2 - Y_1)\ (X_2' + 2\ X_1')}{4.5936 \times 10^{13}}$$

in seconds — in decimal degrees

Signs are very important. Note that on the west side of the central meridian, the X′ values are negative; on the east side the X′ values are positive.

In these formulas, the subscript 1 represents the point where the instrument is, (where the angle is being turned) and the subscript 2 represents the point being sighted.

Since the location of the instrument and the backsight point are known, there is no problem computing the J term for the back sight. For the forward, or "ahead" sight, you must estimate the approximate coordinates for this point.

For any single line: True Azimuth = Grid Azimuth + $\Delta\alpha$ + J

For most purposes, such as running a traverse, if the field angles are turned clockwise from the backsight to the ahead sight, then:

Grid Angle = Field Angle + J (backsight) - J (foresight)

NOTES

1. If the lines are near the central meridian, the X′ values become small and the J terms are negligible.
2. If the line is east-west (or nearly so) the $Y_2 - Y_1$ terms become small and the J terms are negligible.

PROBLEM

All points in Zone 3. Point A is at X = 300,000 Y = 4,100,000. Point B is at X = 280,000 Y = 4,000,000. The approximate location of Point C is X = 300,000 Y = 3,900,000. The field angle, at B, turned clockwise from A to C is 157 22′ 50.0" What is the grid angle, to be used in the state plane computations?

ANSWERS TO PROBLEMS

Page 2	L = 1254.72 L = 7265.31
Page 3	X′ = -42,799.50 X′ = +20,456.90
Page 5	S.F. = 0.9999575 (or 0.9999576) S.F. = 0.9999708 (or 0.9999709) Grid Length = 1456.73
Page 7	Mid coord. X = 278,303 Y = 3,999,470 X′ = -221,697 S.F. = 0.9999559 (or 0.9999560) Grid L. = 14,749.55 Queen at X = 271,006.84 Y = 4,000,539.34
Page 8	Begin X = 560,235 Y = 2,500,765 S.F. = 0.9999041 Mid X = 600,235 Y = 2,530,765 S.F. = 0.9999114 (5) End X = 640,235 Y = 2,560,765 S.F. = 0.9999224 Overall S.F. = 0.9999120 (1) Grid L. = 99,991.20 (.21) Sierra at X = 640,227.54 Y = 2,560,760.12
Page 9	Zone 3 Angle = -1° 45′ 53.2" Zone 4 +1° 49′ 10.4" True Az. 258° 56′ 16.8" Zone 4 Az. 257° 07′ 06.4"
Page 10	Mapping Angle = +1° 03′ 04.8"
Page 11	J back = -5.0" J ahead = +5.0" Grid Angle = 157° 22′ 40.0"

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HORIZONTAL CONTROL DATA
by the
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NORTH AMERICAN 1927 DATUM

T 1.1.2

ALASKA 64147 PAGE NO 1

LATITUDE 64° to 65°
LONGITUDE 147° to 148°
DIAGRAM WAC 77

Station Name	State Code	Zone Code	Latitude	Longitude	G.P. Vol. & Page	Description Page	X Coordinate (feet)	Elevation - meters	Elevation --- feet	Y Coordinate (feet)	θ, Δα, or γ Angle
ACS NO 1 USE 1944	50	03	64 51 30.360	W147 47 43.238	4 040	6	220 701.38			3972 266.02	-01 37 31.3
BALD USE 1944	50	03	64 51 14.025	W147 33 13.247	4 040	6	258 249.58			3969 612.01	-01 24 23.4
BENCH MARK CE 314 1941	50	03	64 51 22.460	W147 48 59.744	4 039	22	217 372.95			3971 557.98	-01 38 40.4
BENCH MARK H 60 1953	50	03	64 49 31.203	W147 50 47.872	4 323	6	212 371.28	131.96	432.9	3960 393.44	-01 40 16.8
	50	04	64 49 31.203	W147 50 47.872			835 392.44			3961 902.96	01 56 56.4
BENCH MARK Z 59 1953	50	03	64 50 14.254	W147 47 43.351	4 323	23	220 477.17	131.99	433.0	3964 536.32	-01 37 30.4
BM US 1922 RESET 1941 1941	50	03	64 46 23.799	W147 26 55.920	4 030	7,8	273 881.29	144.41	473.8	3939 744.77	-01 18 38.7
CHENA EAST BASE 1941	50	03	64 50 56.906	W147 44 15.032	4 030	8	229 603.57	133.25	437.2	3968 616.99	-01 34 22.3
CHENA WEST BASE 1941	50	03	64 51 22.353	W147 51 43.422	4 030	9	210 300.56	141.40	463.9	3971 752.71	-01 41 08.6
	50	04	64 51 22.353	W147 51 43.422			832 608.41			3973 109.14	01 56 07.9
DITCH 1941	50	03	64 50 11.191	W147 54 26.224	4 029	10	203 048.59	269.9	885	3964 734.84	-01 43 35.0
	50	04	64 50 11.191	W147 54 26.224			825 813.96			3965 647.09	01 53 39.4
DORAN 1941	50	03	64 43 35.888	W147 12 45.312	4 028	10	310 426.15	246.8	810	3921 913.09	-01 05 47.6
FAIRBANKS AIRP CONTR TWR 1953	50	03	64 49 08.964	W147 51 42.376	4 323	10	209 947.17	152	499 *	3958 203.84	-01 41 05.8
	50	04	64 49 08.964	W147 51 42.376			833 111.36			3959 564.59	01 56 06.7
FAIRBANKS ALAS RR CO WT 1941	50	03	64 50 56.57	W147 43 42.08	4 038	10	231 027			3968 544	-01 33 52.5
FAIRBANKS ASTRO STATION 1900	50	03	64 50 54.264	W147 43 26.284	4 039	11	231 703.16			3968 291.02	-01 33 38.2

* No check on this elevation

USCOMM–ESSA–ASHEVILLE

THE ALASKA COORDINATE SYSTEM, NAD-83

BY

WILLIAM MENDENHALL, L.S., P.E.

PROFESSOR OF CIVIL ENGINEERING, EMERITUS

UNIVERSITY OF ALASKA FAIRBANKS

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(FAIRBANKS CHAPTERS)

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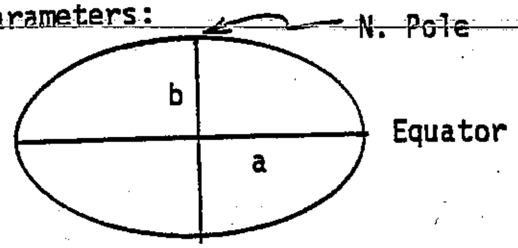
DISCLAIMER

THE ALASKA COORDINATE SYSTEM

The Alaska Coordinate System was originally set up in 1959, and it has been used extensively by both private surveyors and government agencies throughout the state. Alaska was divided into ten zones, with Zone 1 being an Oblique Mercator Projection, Zones 2-9 Transverse Mercator Projections, and Zone 10 a Lambert Conformal Conic Projections. All zones had coordinates in feet. It was based on the 1927 North American Datum, which in turn was based on Clarke's 1866 Ellipsoid.

Over a decade ago, the National Geodetic Survey (NGS) undertook to determine a more accurate shape of the earth, and more accurate location of points. This was done in cooperation with Canada, Mexico, and other countries. The original target date was 1983, so this was to be called the 1983 North American Datum, or sometimes NAD-83. The earth is assumed to be an ellipsoid of revolution with the following parameters:



$a = 6{,}378{,}137$ meters exact

$b = 6{,}356{,}752.31414\ 0347$ meters

$$f = \frac{a - b}{a} = 0.00335\ 28106\ 81183\ 637$$

$$1/f = 298.25722\ 21008\ 827$$

$$e^2 = \frac{a^2 - b^2}{a^2} = 0.00669\ 43800\ 22903\ 416$$

$$e = 0.08181\ 91910\ 42831\ 85$$

$$e'^2 = \frac{a^2 - b^2}{b^2} = 0.00673\ 94967\ 75481\ 622$$

$$e' = 0.08209\ 44381\ 51933\ 42$$

$$n = \frac{a - b}{a + b} = 0.00167\ 92203\ 94629\ 441$$

Meridian length from Equator to Pole = 10,001,965.72922 984 meters

(These values are given for those who wish to write computer programs.)

The Alaska Coordinate System of 1983 is based on this "shape of the earth." It was adopted by the 1984 Alaska State Legislature HCS CSSB 375, Chapter 152, amending Alaska Statutes 38.20.010-100.

It is VERY IMPORTANT to realize that the latitude and longitude of every control point in Alaska (and in fact the entire U.S., except for Fort Wayne, Indiana) will shift. Take, for example, a U.S.C.&G.S. (now NGS) brass cap triangulation point "EAGLE." In the 1927 system, this brass cap has certain latitude and longitude values. Under the 1983 readjustment, this brass cap will be in the same spot on the ground (that is, it will not be physically moved) but (in Alaska) it will have a new latitude value which will make it <u>appear</u> to have moved south, and a new longitude value which will make it <u>appear</u> to have moved west. The meter values of these shifts are shown below.

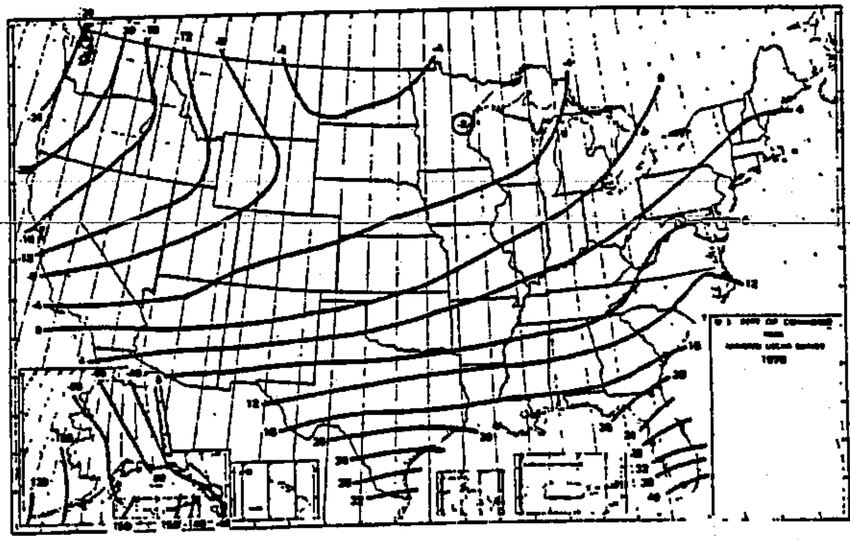


Figure 1.--Expected latitude change from NAD 27 to NAD 83 (in meters).

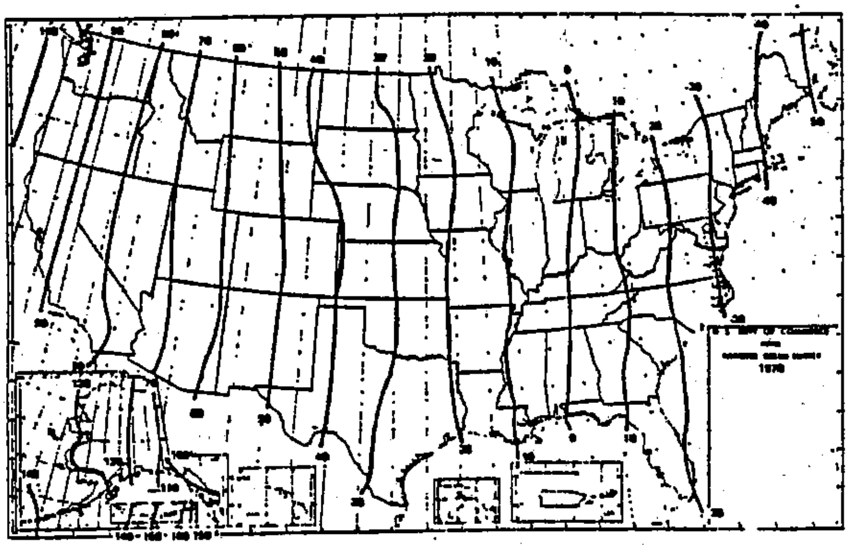


Figure 2.--Expected longitude change from NAD 27 to NAD 83 (in meters).

There is no simple way to convert any 1927 coordinate values to 1983 values. There are several reasons for this.

a. The old 1927 values were in feet; the 1983 values are in meters.

b. The central meridians will physically shift to the east.

c. Zones 7 and 9 will have central meridian constants of 500,000 meters, rather than their old values of 700,000 and 600,000 feet.

d. The Zone 10 central meridian will have a value of 1,000,000 meters, rather than its old value of 3,000,000 feet.

e. The center point of Zone 1, near Kake, will have slightly different coordinates because of the new shape of the earth.

f. Even if everything else remained the same, the mere fact of using a new shape of the earth would change almost all coordinates.

Therefore: DON'T MIX UP THE 1927 SYSTEM WITH THE 1983 SYSTEM.

A map of Alaska is shown on the next page, showing the 10 zones in Alaska.

Here are some of the key values for the 10 zones:

ZONE 1 Center point is at Lat. 57° 00' N., Long. 133° 40' W. (near Kake.)
Grid north for this zone is basically True North at the center point.
The u-axis bears N 36° 52' 11.6315" W at the center point. (The tangent of this angle is 3/4)
The scale factor along the u-axis is 0.9999000.
The Zone 1 values for the center point are E = 818,676.7335 meters
N = 575,097.6887 meters

ZONES 2-9 The central meridians are:

Zone	C.M. Longitude
2	142° W.
3	146° W.
4	150° W.
5	154° W.
6	158° W.
7	162° W.
8	166° W.
9	170° W.

All central meridians have E values of 500,000 meters.

The N value, at the central meridians, for Latitude 54° N., is zero.

Grid norths are the true norths of the central meridians.
All central meridians have scale factors of 0.9999000.

ZONE 10 The central meridian is at 176° W. longitude. This is grid north.
The central meridian has an E value of 1,000,000 meters.
The standard parallels are at 51° 50' N. and 53° 50' N. The scale factors along these standard parallels are exactly 1.0000000.
The N-value of Latitude 51° N. at the central meridian is zero.
The least scale factor is 0.9998481

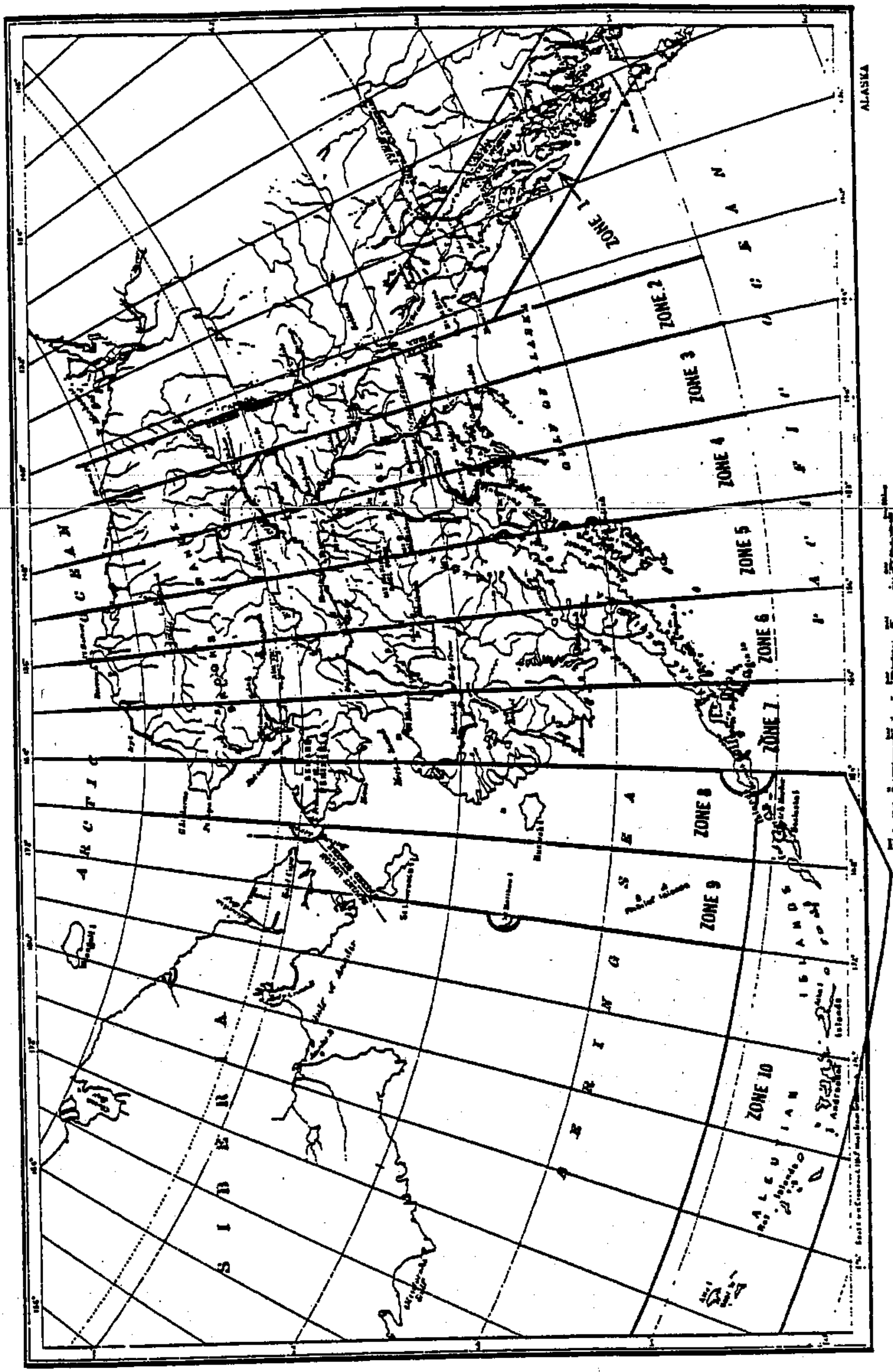

ALASKA
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
ZONE 9
ZONE 10
ARCTIC OCEAN
SIBERIA
BERING SEA
GULF OF ALASKA
PACIFIC OCEAN
ALEUTIAN ISLANDS

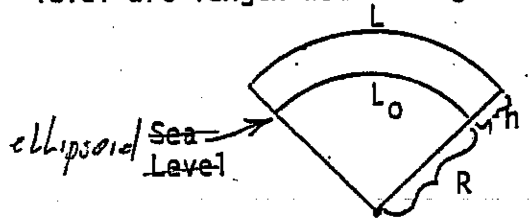
Figure 1.

REDUCTION TO SEA LEVEL (OR THE ELLIPSOID)

Reduce to Ellipsoid

Before doing anything with a length which has been measured by normal surveying methods, if you are to use the coordinate system you must first reduce this measured length to the ellipsoidal surface. For most practical purposes, this is sea level. (Note: reduction to sea level is standard in all states except Michigan.)

Taping. If you were to tape along a level surface, such as a plateau, whose average elevation above sea level (ellipsoid?) is h, then the equivalent sea level arc length would be given by:



$$L_o = \frac{R}{R + h} L$$

where: L is the measured length
h = average elevation above the ellipsoid (sea level is generally used)

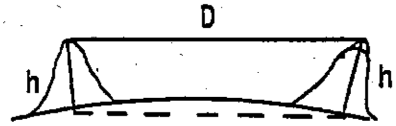
R = average radius of curvature of the earth.

NOTE: R for the "lower 48" is about 6,372,000 meters
R for ALASKA is suggested to be 6,390,000 meters (for about halfway between Anchorage and Fairbanks)

PROBLEM: A plateau has an elevation of about 1400 meters above sea level. You measure a line as being 3124.506 meters long. What is its sea level arc length?

NOTE: A sea level arc length is called a GEODETIC LENGTH.

Level EDM Shots. If you shot EDM betwen two points of equal elevation (h above sea level) and got a distance D, a sea level chord length is given by:



$$\text{Sea Level Chord} = \frac{R}{R + h} D$$

H above ellipsoid

If the distance D is less than about 10 km. long, the difference between the arc and the chord is negligible. For longer distances, the arc will be longer than the chord by: $1.02 \times 10^{-15} D^3$

PROBLEM: Two EDM instruments are each 3145 meters above sea level. The EDM distance D is given as 23,456.78 meters (about 15 miles.) What is the geodetic length? (Sea level arc length.)

Non-Level EDM Shots.

A. Non-reducing instruments. Somehow, either through trigonometric leveling, or other methods, you must get the elevations of both EDM units. The preferable way is to use reciprocal zenith angles. Then the difference in elevation between point 1 and point 2 is:

$$h_2 - h_1 = D \sin\left(\frac{Z_2 - Z_1}{2}\right)$$

where Z_1 = zenith angle at point 1
Z_2 = zenith angle at point 2

If only <u>one</u> zenith angle is measured (at point 1), then:

$$h_2 - h_1 = D \cos Z_1 + 6.82 \times 10^{-8} [D \sin Z_1]^2$$

Knowing the two elevations of the instruments (call these h_1 and h_2) the geodetic length is:

$$\text{Geod. chord} = \frac{R}{R + \left(\frac{h_1 + h_2}{2}\right)} \sqrt{D^2 - (h_2 - h_1)^2}$$

$$\text{Geodetic arc} = \text{Geodetic chord} + 1.02 \times 10^{-15} (\text{Chord})^3$$

PROBLEM: EDM unit at A is at elevation 1200 meters. The EDM unit at B is at elevation 1400 meters. The EDM slope distance (D) between the two units is 15,456.78 meters. What is the geodetic distance between A and

B. Reducing Instruments. Many total stations now can account for earth's curvature and atmospheric refraction. On many of these units, when you measure the EDM slope distance, you can either punch into a computer the zenith angle, or have a sensor "send" the angle to a computer. Then, by merely pressing a button marked Horiz., or something similar, you get a "Horizontal" Distance. What you are really getting is an equivalent horizontal chord at the elevation of the total station. This chord must then be reduced to sea level based on the elevation of the total station.

PROBLEM: A total station is at elevation 867 meters. A shot is taken to nine remote prisms, and the "Horiz" button is pushed. The readout indicates 5432.107 meters. What is the geodetic distance from the total station to the remote prisms?

SCALE FACTORS

The surveying measurements on the earths surface are made on an almost spherical surface. A sphere cannot be made into a flat surface. To get a flat (Plane) surface, certain distortions occur. One of these distortions means that measured lengths (even at sea level) must be slightly modified to get "plane coordinate grid" lengths. These modifying ratios, or fudge factors, are called scale factors.

State Plane Grid Length = Geodetic Length X Scale Factor

(Trivia Note: In Michigan, Grid Length = <u>800 ft.</u> length x scale factor)

It is seen why the importance has been placed on Geodetic (Sea level arc) Lengths All surveying measurements MUST be reduced to geodetic lengths before they can then be converted into GRID lengths, which are the lengths to be used in State Plane Coordinate Systems.

PROBLEM: Line AB has a geodetic length of 3141.567 meters. The average scale factor for line AB is 0.9999025. What is the Grid Length of AB?

"COMBINATION" FACTORS

Some surveying companies working on a small project like to combine the computations of reducing to sea level and applying the scale factor into one "combined" factor. The idea is to imagine a length one meter long at the elevation of the project. This length would then be reduced down to sea level to get its geodetic length, and then this geodetic length would be multiplied by the scale factor to get the grid length.

PROBLEM: You are making a survey for a small airport project at 876 meters above sea level. The scale factor at the center of the project is 0.9999103.

A, What is the "combined" factor?

B. For this airport survey, you make horizontal measurements shown below. What are the equivalent "grid" lengths?

765.432 meters

1301.786 meters

945.734 meters

MAPPING ANGLES

For each zone, there is a grid north which corresponds to true north at the center of the zone. All "grid" norths are parallel. Of course, all true norths must meet at the north pole, so they cannot be parallel. In fact, the lack of parallelism of true norths is one of the main reasons these various grid systems were invented.

At any point in a plane coordinate zone, there is an angular relation between grid north and true north at that point. This angular relation is called the "mapping angle." For the three different types of projections, there is a special nomenclature for the mapping angle.

For Oblique Mercator projections, it is called	γ	(gamma)
For Transverse Mercator projections " "	$\Delta\alpha$	(delta alpha)
For Lambert Conformal Conic " " "	θ	(theta)

No matter what it is called, these values are always positive when east of the central meridian, or east of the center point. They are always negative when west of the central meridian, or center point.

TRUE Azimuth = GRID Azimuth + Mapping Angle

This statement is true for what we will call "short" lines, say less than about 10 miles (15 km.) long. We will later modify this statement.

$\tan \Delta\alpha = \sin \phi \tan \Delta\lambda$

PROBLEM: Short line CD has a true azimuth of 65° 43' 10". The mapping angle is + 2° 47' 56". What is the grid azimuth of this line?

NOTE: Effective with the 1983 adjustment, the National Geodetic Survey, and other government agencies, will measure azimuths clockwise from true north. Prior to 1983, they measured clockwise from true south.

PROBLEM: Short line MN has a grid bearing of S 35° 20' 15" E. The mapping angle is -0° 34' 56". What is the true bearing of line MN?

COORDINATE COMPUTATIONS

So that we don't get carried away by too many exotic thoughts, let's review some simple coordinate computations.

Grid "northings" (latitudes) = Grid lengths x Cosine of Grid Azimuth

Grid "eastings" (departures) = Grid lengths x Sine of Grid Azimuth

Here is where the polar to rectangular key comes in handy.

For inverses: Grid length = $\sqrt{(E_2 - E_1)^2 + (N_2 - N_1)^2}$

Grid Azimuth from 1 to 2 = $\tan^{-1}\left(\frac{E_2 - E_1}{N_2 - N_1}\right)$ (If angle is negative, add (If the answer looks bad, add or subtract 180°)

PROBLEM: Point A has Zone 4 coordinates of (Mickey Mouse values)

E = 540,000.000 m. N = 1,030,000.000 m.

Line AB has a grid azimuth of 310° 00' 00" and a grid length of 2000.00

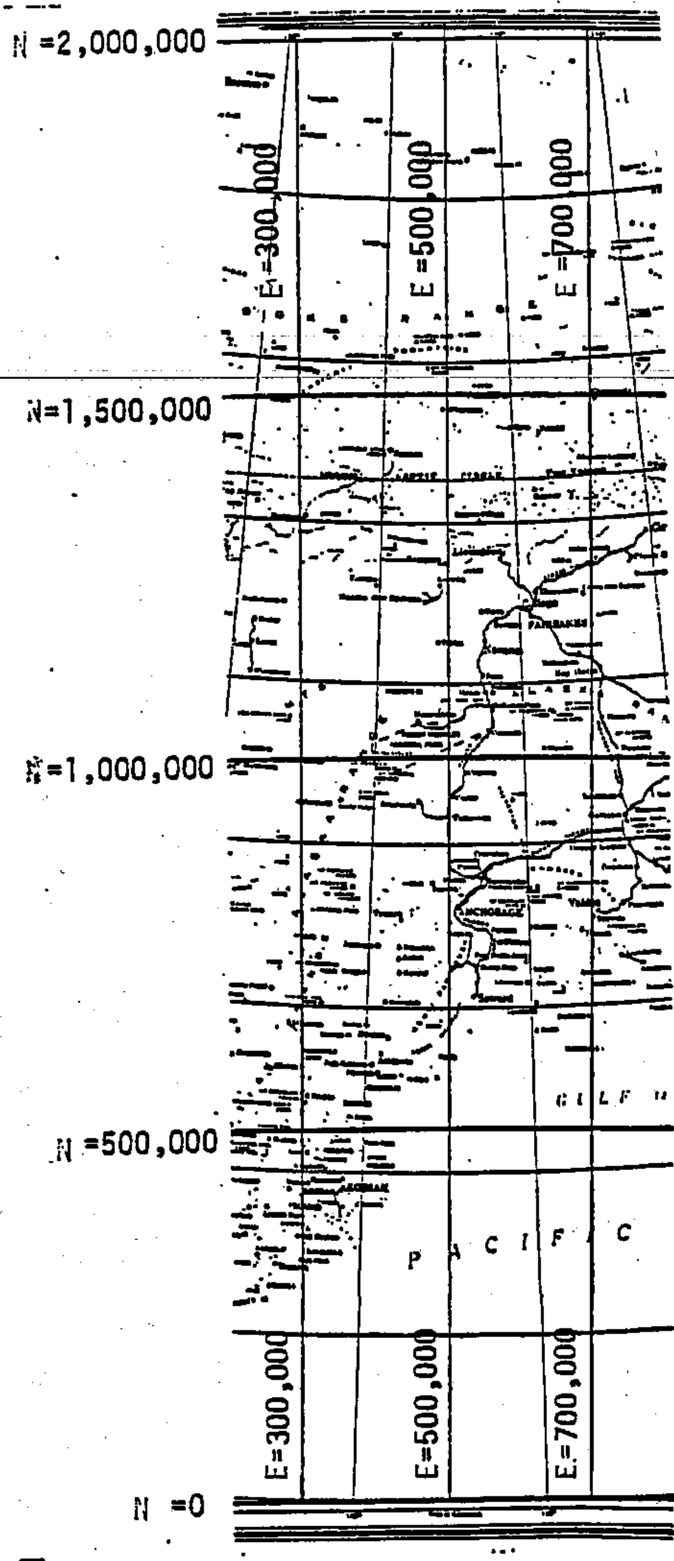
What are the Zone 4 coordinates of point B?

PROBLEM: Point Q is at E = 530,000.000 N = 1,000,000.000
Point R is at E = 520,000.000 N = 1,020,000.000

What is the grid length of line QR? What is the grid azimuth from Q to

ALASKA ZONES 2-9 LAYOUT OF A TYPICAL ZONE

Below is a layout of Zone 4. The Central Meridian is Long. 150° W. The E value of the C.M. is 500,000. The intersection of the 54° N. Latitude line, and the C.M. has a N. value of zero.



THE TEN ZONES OF ALASKA

Up till now, we have discussed many principles in <u>general</u> terms, applicable to just about any state plane coordinate zone. We will now discuss the zones of Alaska in great detail. Let's start with Zones 2-9.

ALASKA ZONES 2 - 9

In any one of these eight zones, points will have an E coordinate (always positive) ranging from about 300,000 meters to about 700,000 meters. The center of the zone (the central meridian) has an E value of 500,000 meters exactly. The N values will always be positive, and will range from a few hundred thousand up to about two million.

You should be familiar with E values. In zones 2-9, you should also be familiar with E' (pronounced E -<u>prime</u>) values.

$$E' = E \text{ coordinate} - 500{,}000$$

PROBLEM: Point Delta has coordinates of E = 564,376.543 N = 1,056,234.876. What is the E' value for point Delta?

PROBLEM: Point Echo has coordinates of E = 415,987.345 N = 765,234.876 What is the E' value for point Echo?

SCALE FACTORS

If you know the location, or even the approximate location, of a point in Zones 2-9, you can determine the scale factor.

ZONE 2-9 $S.F. = 0.9999 + [1.22657 \times 10^{-14} - 2.06 \times 10^{-23} N] (E')^2$

This formula works over the entire range of zones 2-9. Note that there is a value in the brackets. If you know the approximate values for the N's in your survey area, you can simplify this formula.

If the N values are near zero,	$S.F. = 0.9999 + 1.22668 \times 10^{-14}(E')^2$
If the N values are near 500,000	$S.F. = 0.9999 + 1.22549 \times 10^{-14}(E')^2$
If the N values are near 1,000,000	$S.F. = 0.9999 + 1.22439 \times 10^{-14}(E')^2$
If the N values are near 1,500,000	$S.F. = 0.9999 + 1.22341 \times 10^{-14}(E')^2$
If the N values are near 2,000,000	$S.F. = 0.9999 + 1.22257 \times 10^{-14}(E')^2$

PROBLEM: At E = 584,500 N = 1,030,000 what is the scale factor?

SCALE FACTORS ZONES 2-9

E'	S.F.	E'	S.F.	E'	S.F.	E'	S.F.
0	0.9999000						
1000	0.9999000	51000	0.9999318	101000	1.0000249	151000	1.0001792
2000	0.9999000	52000	0.9999331	102000	1.0000274	152000	1.0001829
3000	0.9999001	53000	0.9999344	103000	1.0000299	153000	1.0001866
4000	0.9999002	54000	0.9999357	104000	1.0000324	154000	1.0001904
5000	0.9999003	55000	0.9999370	105000	1.0000350	155000	1.0001941
6000	0.9999004	56000	0.9999384	106000	1.0000376	156000	1.0001980
7000	0.9999006	57000	0.9999398	107000	1.0000402	157000	1.0002018
8000	0.9999008	58000	0.9999412	108000	1.0000428	158000	1.0002056
9000	0.9999010	59000	0.9999426	109000	1.0000455	159000	1.0002095
10000	0.9999012	60000	0.9999441	110000	1.0000481	160000	1.0002134
11000	0.9999015	61000	0.9999455	111000	1.0000508	161000	1.0002174
12000	0.9999017	62000	0.9999470	112000	1.0000536	162000	1.0002213
13000	0.9999021	63000	0.9999486	113000	1.0000563	163000	1.0002253
14000	0.9999024	64000	0.9999501	114000	1.0000591	164000	1.0002293
15000	0.9999027	65000	0.9999517	115000	1.0000619	165000	1.0002333
16000	0.9999031	66000	0.9999533	116000	1.0000647	166000	1.0002374
17000	0.9999035	67000	0.9999549	117000	1.0000676	167000	1.0002415
18000	0.9999040	68000	0.9999566	118000	1.0000705	168000	1.0002456
19000	0.9999044	69000	0.9999583	119000	1.0000734	169000	1.0002497
20000	0.9999049	70000	0.9999600	120000	1.0000763	170000	1.0002538
21000	0.9999054	71000	0.9999617	121000	1.0000792	171000	1.0002580
22000	0.9999059	72000	0.9999635	122000	1.0000822	172000	1.0002622
23000	0.9999065	73000	0.9999652	123000	1.0000852	173000	1.0002664
24000	0.9999070	74000	0.9999670	124000	1.0000882	174000	1.0002707
25000	0.9999076	75000	0.9999689	125000	1.0000913	175000	1.0002750
26000	0.9999083	76000	0.9999707	126000	1.0000944	176000	1.0002793
27000	0.9999089	77000	0.9999726	127000	1.0000975	177000	1.0002836
28000	0.9999096	78000	0.9999745	128000	1.0001006	178000	1.0002879
29000	0.9999103	79000	0.9999764	129000	1.0001037	179000	1.0002923
30000	0.9999110	80000	0.9999783	130000	1.0001069	180000	1.0002967
31000	0.9999117	81000	0.9999803	131000	1.0001101	181000	1.0003011
32000	0.9999125	82000	0.9999823	132000	1.0001133	182000	1.0003056
33000	0.9999133	83000	0.9999843	133000	1.0001166	183000	1.0003100
34000	0.9999141	84000	0.9999864	134000	1.0001198	184000	1.0003145
35000	0.9999150	85000	0.9999884	135000	1.0001231	185000	1.0003190
36000	0.9999159	86000	0.9999905	136000	1.0001264	186000	1.0003236
37000	0.9999167	87000	0.9999927	137000	1.0001298	187000	1.0003281
38000	0.9999177	88000	0.9999948	138000	1.0001332	188000	1.0003327
39000	0.9999186	89000	0.9999970	139000	1.0001365	189000	1.0003373
40000	0.9999196	90000	0.9999992	140000	1.0001400	190000	1.0003420
41000	0.9999206	91000	1.0000014	141000	1.0001434	191000	1.0003467
42000	0.9999216	92000	1.0000036	142000	1.0001469	192000	1.0003513
43000	0.9999226	93000	1.0000059	143000	1.0001504	193000	1.0003561
44000	0.9999237	94000	1.0000082	144000	1.0001539	194000	1.0003608
45000	0.9999248	95000	1.0000105	145000	1.0001574	195000	1.0003656
46000	0.9999259	96000	1.0000128	146000	1.0001610	196000	1.0003703
47000	0.9999270	97000	1.0000152	147000	1.0001646	197000	1.0003752
48000	0.9999282	98000	1.0000176	148000	1.0001682	198000	1.0003800
49000	0.9999294	99000	1.0000200	149000	1.0001718	199000	1.0003849
50000	0.9999306	100000	1.0000224	150000	1.0001755	200000	1.0003897

CORRECTION TO SCALE FACTOR (7th Decimal Place)

N \ E'	0	25,000	50,000	75,000	100,000	125,000	150,000	175,000	200,0
2,000,000	0	0	-1	-1	-2	-3	-4	-6	-7
1,500,000	0	0	0	-1	-1	-2	-2	-3	-4
1,000,000	0	0	0	0	0	0	0	0	0
500,000	0	0	0	+1	+1	+2	+3	+3	+4
0	0	0	+1	+1	+2	+4	+5	+7	+9

ZONES 2-9 SCALE FACTOR CORRECTION FOR LONG LINES

Corrections (plus) to 7th decimal place

Δ E	Corr.	Δ E	Corr.	Δ E	Corr.
0	0				
1000	0	41000	17	81000	67
2000	0	42000	18	82000	69
3000	0	43000	19	83000	71
4000	0	44000	20	84000	72
5000	0	45000	21	85000	74
6000	0	46000	22	86000	76
7000	1	47000	23	87000	77
8000	1	48000	24	88000	79
9000	1	49000	25	89000	81
10000	1	50000	26	90000	83
11000	1	51000	27	91000	85
12000	1	52000	28	92000	87
13000	2	53000	29	93000	89
14000	2	54000	30	94000	90
15000	2	55000	31	95000	92
16000	3	56000	32	96000	94
17000	3	57000	33	97000	96
18000	3	58000	34	98000	98
19000	4	59000	36	99000	100
20000	4	60000	37	100000	102
21000	5	61000	38	101000	104
22000	5	62000	39	102000	106
23000	5	63000	41	103000	109
24000	6	64000	42	104000	111
25000	6	65000	43	105000	113
26000	7	66000	45	106000	115
27000	7	67000	46	107000	117
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36000	13	76000	59	116000	138
37000	14	77000	61	117000	140
38000	15	78000	62	118000	143
39000	16	79000	64	119000	145
40000	16	80000	66	120000	147

NOTE: These values are based on the formula:

$$\text{Correction} = 1.0236 \times 10^{-15} (\Delta E)^2$$

The main portion of the tables on the page 12 was based on N values near one million (1,000,000.) If the N value is significantly different from one million, you should check the "bottom of the page" to see if a correction needs to be made in the 7th decimal place.

PROBLEM: (Same as last proble, except to be done with the tables.) At E=584,500 N = 1,030,000 what is the scale factor?

PROBLEM: At E = 310,000 N = 80, 000 what is the scale factor?

SCALE FACTORS FOR SHORT LINES

Rule. For short lines, estimate the midpoint of the line, find the Scale Factor there, and use that scale factor for the entire line.

Grid Length = Geodetic Length x S.F. at midpoint

PROBLEM: Point A has coordinates of Zone 4 E = 528,000 N = 1,500,000. Line AB has a Zone 4 grid azimuth of 30° 00' and a geodetic length of 4000 meters. What are the Zone 4 grid coordinates of Point B?

SCALE FACTORS ON LONG LINES

There are two rules, either of which, but not both, may be used.

Rule 1. (Simpson's Rule) For a long line, estimate the location of the midpoint, and also the location of the far end. You already know the location of the beginning of the line.

$$\text{Scale Factor for the whole line} = \frac{SF_1 + 4\,SF_m + SF_2}{6}$$

where SF_1 = scale factor at the beginning of the line
SF_m = scale factor at the estimated midpoint of the line
SF_2 = scale factor at the estimated end of the line

Rule 2. For a long line, estimate the location of the midpoint of the line. Determine the-scale factor at the midpoint. Then, using the approximate difference in the coordinates of the ends of the line, add (always add) the Delta E (ΔE) Correction to the 7th decimal place. The result will be the overall scale factor to use for the entire line.

PROBLEM: (Mickey Mouse) Point A is at Zone 3 E = 650,000 N = 1,940,000. Line AB heads grid east (exactly grid east) and has a geodetic length of 50,000 meters. What are the coordinates of point B?

Method 1. (Simpson's Rule)

Method 2. (The delta E method)

PROBLEM: Point Q is at Zone 2 E = 345,678.900 N = 546,800.250 Line QR has a grid azimuth of 107° 23' 45.60" and a geodetic length of 62,333.333 meters. What are the coordinates of point R?

AREAS

Areas will be dealt with only in Zones 2 thru 9. However the same principles apply to Zone 1 and Zone 10.

Rule: To find the true surface area at sea level (really on the ellipsoid) find the area based on state plane coordinates, using one of the standard methods such as D.M.D's, or else coordinates. Next, estimate the location of the centroid of the area. Then, find the scale factor at this centroid. Finally, divide the plane coordinate area by the square of the scale factor at the centroid. You will now have the surface area at sea level.

Rule: If you want the true surface area at the real elevation, find the "combined" factor at the centroid of the area. Divide the plane coordinate area by the square of the combined factor to get the true surface area.

PROBLEM: A certain closed traverse, using coordinates, has a plane coordinate area of 765.432 hectares. The centroid of the area is near Zone 4 E = 530,000 N = 1,600,000.

A. What is the sea-level area of this traverse?

B. This area is really at an elevation of 1430 meters. What is the true surface area?

NOTE: One hectare contains 10,000 square meters. One way to remember this; if the shape is a perfect square, then a hectare is 100 meters on each side.

One km^2 contains 100 hectares.

For farmers: one hectare is equivalent to about 2.471 acres. (Easy to remember: one hectare = 2.5 acres approximately

ZONES 2-9 MAPPING ANGLES

Zones 2-9 are Transverse Mercator Projections. For this type of projection, the mapping angle is called delta alpha ($\Delta\alpha$) In the eastern half of the zone (east of the central meridian) it is positive; in the western half, it is negative.

Remember: True Azimuth = Grid Azimuth + Mapping Angle

It is time to introduce a quantity known as delta lambda ($\Delta\lambda$) The symbol delta is a standard mathematical symbol referring to differences. The symbol lambda is a standard geodetic term representing longitude. Therefore, delta lambda stands for a difference in longitude. This is the difference in longitude between a location, and the longitude of the central meridian.

Rule: $\Delta\lambda$ = Longitude of the Central Meridian - Longitude of any Poin

---

PROBLEM: In Zone 4, what is the $\Delta\lambda$ value for a point whose longitude is 148° 24' W?

PROBLEM: In Zone 3, what is the $\Delta\lambda$ value for a point whose longitude is 147° 50' W?

MAPPING ANGLE $\Delta\alpha$ WHEN LATITUDE AND LONGITUDE ARE KNOWN (or can be easily scaled off a U.S.G.S. map.)

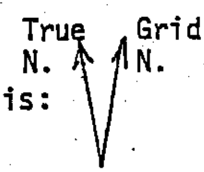
$$\tan(\Delta\alpha) = \tan(\Delta\lambda)\sin(\phi)$$

In this formula ϕ represents the latitude of the point.

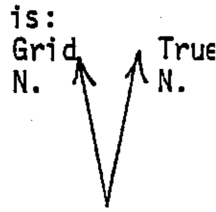
Note: In Alaska, this formula should give a value of $\Delta\alpha$ accurate to about 0.02" (0.02 seconds of angle.)

SIGN OF THE MAPPING ANGLE

East of the Central Merdian $\Delta\alpha$ is + and the angular relation is:



West of the Central Meridian $\Delta\alpha$ is - and the angular relation is:



PROBLEM: A point is at Latitude 62° 20' N., Longitude 148° 30' W. Sketch the angular relationship between Zone 4 grid north and True north.

PROBLEM: A Point is at Latitude 64° 23' 56" N., Longitude 147° 51' 34" W. Sketch the angular relationship between Zone 3 grid north and true nor

MAPPING ANGLE WHEN AND COORDINATES ARE KNOWN

Usually, you don't know latitudes and longitudes unless you are right on some NGS control point. You should be able to determine the and state Plane Coordinates for almost any point in a survey, however.

In Zones 2 - 9, the mapping angle can be computed to an accuracy of about 0.3" by using the formula:

$$\tan(\Delta\alpha) = \sin[1.570657\times10^{-7}(E-500{,}000)]_{rad}\ \tan[0.940561 + 1.568475\times10^{-7}\ N]_{rad}$$

Important Note: the little "rad" at the end of each pair or brackets means that before you press the sine or tangent key on your calculator, the calculator must be in radian mode.

Trivia: For a mapping angle accuracy of about 0.03" (ten times the accuracy of the preceding formula) use, in the second pair of brackets:

$$\tan[0.9405841 + 1.567635\times10^{-7}\ N + 4.098\times10^{-17}\ N^2]_{rad}$$

PROBLEM: (Use simpler equation.) At Zone 4 E = 600,000 exact N = 1,500,000 ex what is the angular relationship between Zone 4 grid north and True no

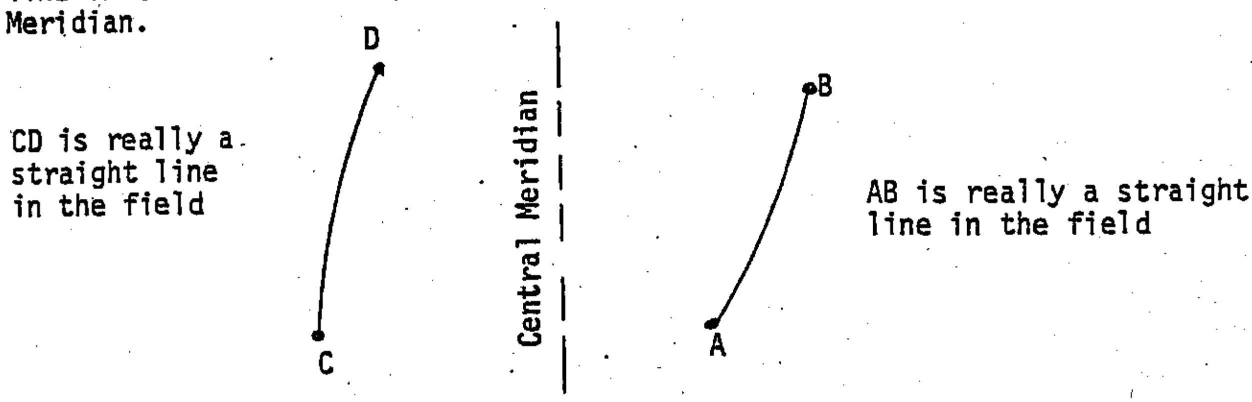
SECOND TERM CORRECTIONS

For longer lines, especially those lines which have a considerable north-south extent, and which are rather far from the Central Meridian, some corrections have to be made to obtain accurate directions. Technically, a little correction must be made, and it is known as either:

2nd term correction
T - t correction
arc-to-chord correction.

These names became rather awkward to use. About 1965, there was a popular expression "and all that jazz." Prof. Mendenhall began to use, strictly on a local basis, the term "that jazz" for this correction, which he later shortened to simply the letter J. Doing some work with a well-known surveying book "Surveying for Civil Engineers" by the late Philip Kissam, Mendenhall discovered that by sheer coincidence Prof. Kissam was also using the term "J." Since this is by far easier to type that the other official names, we will use the letter J in this booklet.

If you set up a theodolite above point A, and sight on a rangepole or other target at point B, you know deep in your heart that you are looking in a straight line. Neglecting refraction (which curves in the vertical direction) and worrying about horizontal directions only, your line of sight really is a straight line. Due to some distortion problems which occur with almost any plane projection, this (really) straight line plots up on the Transverse Mercator grid as a slightly curved line. On Zones such as Alaska 2-9, what is really a straight line in the field will appear as a line slightly bulged away from the Central Meridian.



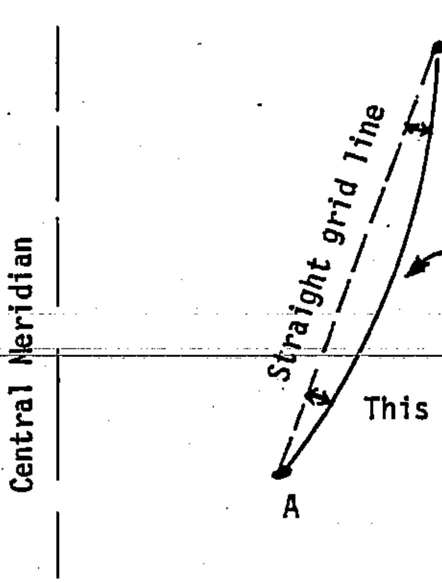
Note: Lines near the central meridian have negligible bulge.
East-west lines anywhere have negligible bulge.

Before proceeding with an explanation of the J term, two subscripts must be made absolutely clear.

Wherever your theodolite is, this is considered point 1. (one)

Whatever you are sighting (the target, range pole, or prism) this is considered to be point 2 (two)

If you plot two points A and B on a plane coordinate system, and you connect these two points with a straight line on the coordinate system, then this straight line will have a constant grid direction, or grid azimuth. There will be two small angles, (one at each end of the line) between this straight line and the bulging line.



J ANGLE FORMULAS

In Alaska Zones 2-9, if you wish to compute the J angle in decimal degrees

$$J^{\circ} = \frac{(N_2 - N_1)(E'_2 + 2E'_1)}{4.2676 \times 10^{12}}$$

If you wish to compute the J angle in seconds of arc

$$J'' = \frac{(N_2 - N_1)(E'_2 + 2E'_1)}{1.1854 \times 10^{9}}$$

Remember that the E' values are really E - 500,000. Pay strict attention to si

If you are turning an angle at point A, then the theodolite is at point A, and point A is the same as point 1. You are sighting point B, so point B is the same as point 2. The formula gives you the J angle at A.

If you are set up at point B, then to compute the J angle at B, consider point B as point 1, and point A as point 2.

PROBLEM: Refer to sketch on preceding page. Point A is at Zone 4 $E = 650,000$ $N = 1,000,000$. Point B is at Zone 4 $E = 670,000$ and $Y = 1,030,000$.

What is the J angle at point A?

What is the J angle at point B?

TRUE (GEODETIC) AZIMUTHS AND GRID AZIMUTHS FOR LONG LINES

If you wish to convert between grid azimuth and true azimuth of a long line: Assume that your theodolite is at point A, and you are sighting distant object B

True azimuth from A to B (based on true north at A) = Grid azimuth (from A to B) + $\Delta\alpha$ (at A) + J angle (at point A)

(A is point 1, B is point 2

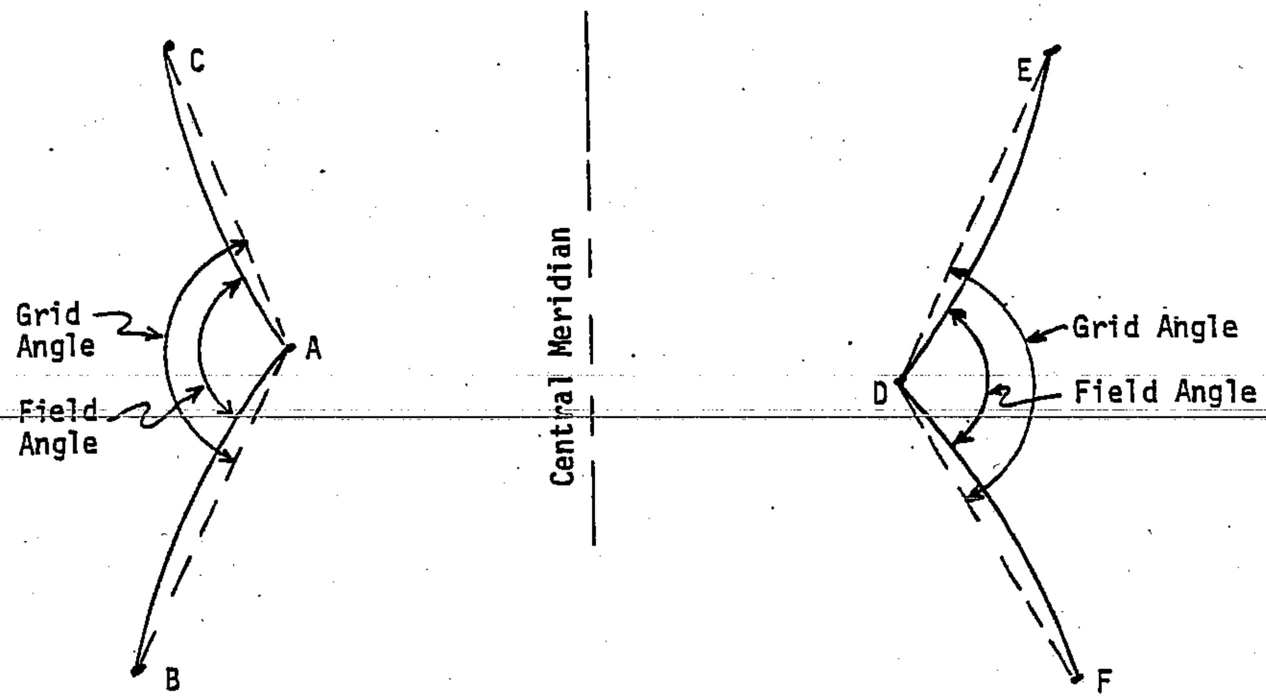
PROBLEM: (see problem above) In the problem above, where A is at $E=650,000$ $N = 1,000,000$ and B is at $E=670,000$ $N = 1,030,000$ what is the true azimuth from A to B (based on true north at A) and what is the true azimuth from B to A (based on true north at B)

Note: to save you some trouble, I've computed $\Delta\alpha$ at A = +2.6331749°
$\Delta\alpha$ at B = +3.0184449°

(these are extreme examples; these points are really outside of Zone 4 and actually overlap into Zone 3. I've used them to give extreme examples of values.)

FIELD ANGLES TO GRID ANGLES

Suppose you turn an angle with both sights being quite long. You wish to convert this "field" angle into an appropriate "grid" angle.



If you turn all angles clockwise (normal theodolite practice) and if you call the first point sighted as the backsight, and the other point sighted as the foresight or the ahead sight, then:

$$\text{Grid angle} = \text{Field Angle} + J_{\text{backsight}} - J_{\text{ahead sight}}$$

If you set up a theodolite at A, backsight on B and turn clockwise to C, then B is the backsight, and C is the ahead sight.

If you set up a theodolite at D, backsight on E and turn clockwise to F, then E is the back sight, and F is the ahead sight.

PROBLEM: (see sketch above) The field angle turned at A was exactly 120°.
With the theodolite at A, the J angle when sighting B is +10.0"
the J angle when sighting C is - 9.0"
What is the grid angle at A?

PROBLEM: The field angle at D was 114° 34' 45.3". The J angle when sighting point E was + 7.3" and the J angle when sighting at F was -6.5"
What is the grid angle at D?

ALASKA ZONE 1

The Alaska State Plane Coordinate System, Zone 1 is an Oblique Mercator projection. It is quite unique; there is no other system in the United States quite like it.

About four decades ago, Brigadier (corresponds to U.S. Brigadier General) Martin Hotine developed an oblique Mercator system for the then British colony of Malaya (now the independent country of Malaysia.)

The National Geodetic Survey has adopted the same methods for the Alaska Zone 1 projection. Many of their formulas look fierce, since they involve hyperbolic functions, but they are really not all that bad. In this short course, we will not try to expect a complete understanding of the mathematics of the system, but just remember, there is no other U.S. system like it.

If you were to look at a map of Southeastern Alaska (the Panhandle) and try to locate the centroid of the area, it would fall somewhere near the village of Kake. An exact point was picked, at Lat. 57° N., Long. 133° 40' W. as the exact center. This is just a few miles east of the village of Kake, but from now on, in this course, we will refer to the center as merely "Kake." (Philosphical question: Has any one ever told the residents of Kake of the great importance of their village?)

True North at Kake corresponds to Grid North for Alaska Zone 1.

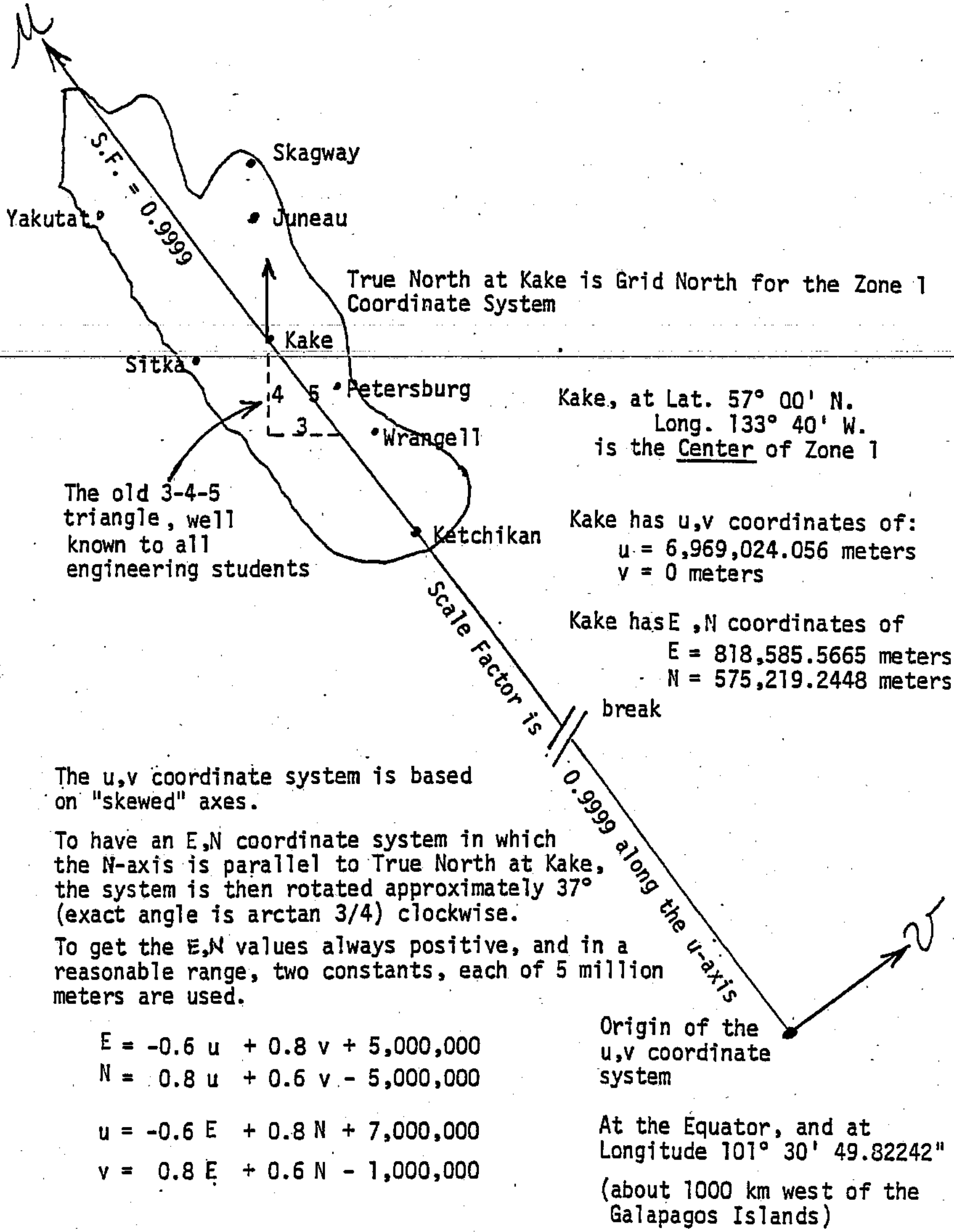
If you were to start out at N 37° W, and S 37° E (approximately) and keep extending this line in both directions (of course the true azimuth keeps changing, since true north keeps changing as you proceed along this line) you would have a line which just about bisects southeastern Alaska. This line is called the u-axis.

As far as scale factor is concerned, this u-axis acts just like a central meridian in Zones 2-9. The scale factor along this u-axis is exactly 0.9999, just as the scale factors along the central meridians of zones 2-9 were 0.9999. No matter whether you head somewhat northeast, or somewhat southwest from this axis, the scale factor increases.

In zones 2-9, the perpendicular distances from the central meridians were called E' (positive to the east, and negative to the west.) In Zone 1, distances perpendicular to the u-axis are called v (positive to the northeast, and negative to the southwest.)

Diagrams and maps on the next two pages may help to clarify some of these concepts.

THE "BIG PICTURE" OF ALASKA ZONE 1



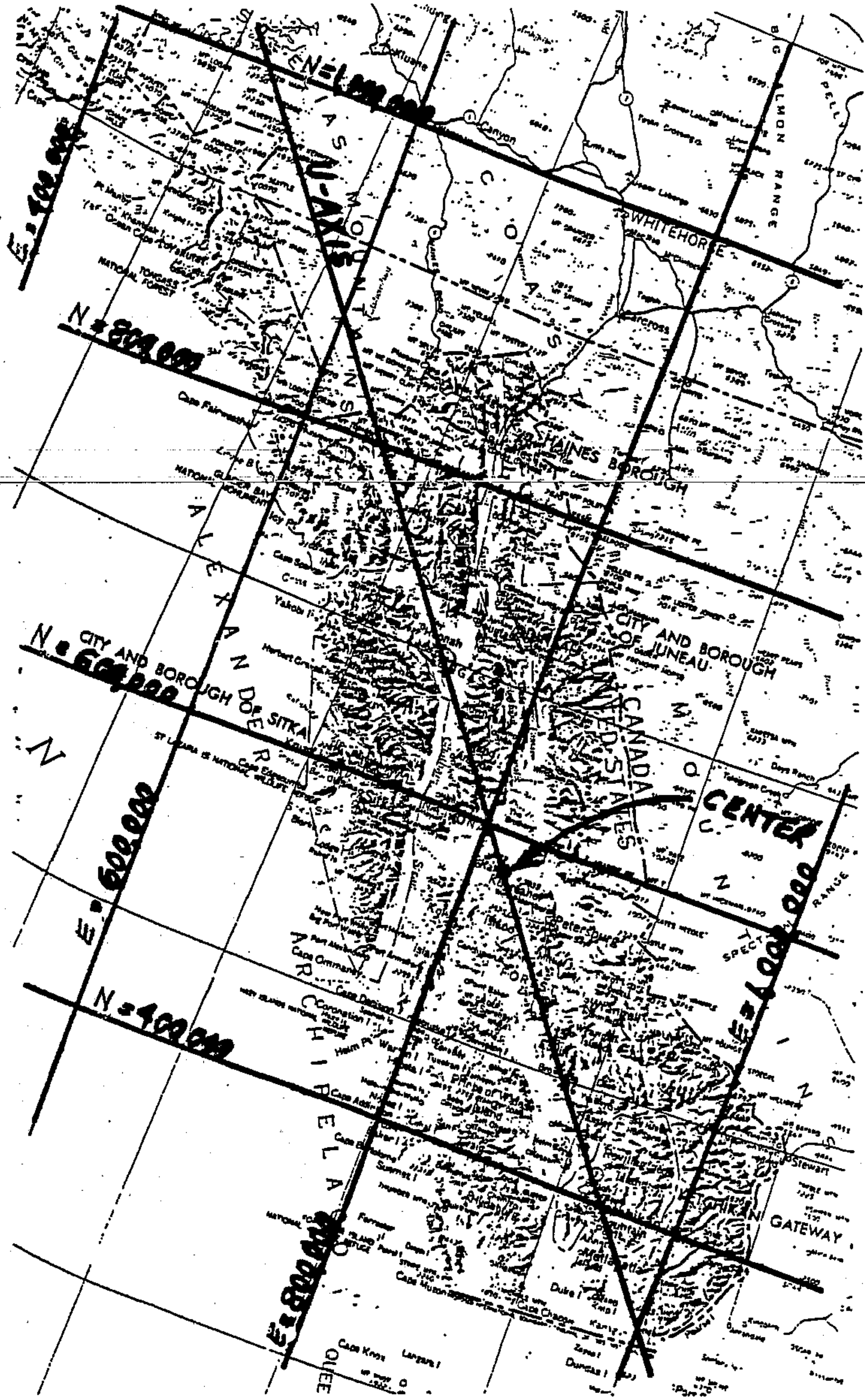
The u,v coordinate system is based on "skewed" axes.

To have an E,N coordinate system in which the N-axis is parallel to True North at Kake, the system is then rotated approximately 37° (exact angle is arctan 3/4) clockwise.

To get the E,N values always positive, and in a reasonable range, two constants, each of 5 million meters are used.

$$E = -0.6\,u + 0.8\,v + 5{,}000{,}000$$
$$N = 0.8\,u + 0.6\,v - 5{,}000{,}000$$

$$u = -0.6\,E + 0.8\,N + 7{,}000{,}000$$
$$v = 0.8\,E + 0.6\,N - 1{,}000{,}000$$


N-AXIS
N=800,000
N=600,000
N=400,000
E=400,000
E=600,000
E=800,000
CENTER
WHITEHORSE
HAINES BOROUGH
CITY AND BOROUGH OF JUNEAU
CITY AND BOROUGH OF SITKA
CANADA
UNITED STATES
KETCHIKAN GATEWAY
Canyon
Carcross
Stewart

SCALE FACTORS IN ALASKA ZONE 1

In Zones 2-9, the scale factors depended on how far away you are from the central meridian. This distance is called E'.

If you look at the "Big Picture" sketch, you can see that the distance away from the u-axis is called v. (v is positive to the northeast, and negative to the southwest.)

Normally, in a survey, you keep track of your E and N coordinates. If you know either the exact, or approximate, coordinates in the E,N system, you can easily compute the v value.

$$v = 0.8\,E + 0.6\,N - 1{,}000{,}000$$

PROBLEM: Near Juneau, you are at Zone 1 E = 760,000 N = 710,000
How far away are you from the u-axis? (In other words, what is the v-value?)

PROBLEM: Near Sitka, you are at Zone 1 E = 710,000 N = 590,000.
How far away are you from the u-axis?

Although it might be useful to have a scale factor formula involving values of v and u, it seems more practical to have a formula based on the v values, and also the approximate N values. A very good formula for Alaska Zone 1 is:

$$S.F. = 0.9999 + [1.22689 \times 10^{-14} - 2.05 \times 10^{-23}\,N]\,(v)^2$$

If you are working in an area where the N values are known at least approximately

If the N values are near 300,000	$S.F. = 0.9999 + 1.22628 \times 10^{-14}\,(v)^2$
near 400,000	$S.F. = 0.9999 + 1.22067 \times 10^{-14}\,(v)^2$
near 500,000	$S.F. = 0.9999 + 1.22587 \times 10^{-14}\,(v)^2$
near 600,000	$S.F. = 0.9999 + 1.22566 \times 10^{-14}\,(v)^2$
near 700,000	$S.F. = 0.9999 + 1.22546 \times 10^{-14}\,(v)^2$
near 800,000	$S.F. = 0.9999 + 1.22525 \times 10^{-14}\,(v)^2$
near 900,000	$S.F. = 0.9999 + 1.22505 \times 10^{-14}\,(v)^2$
near 1,000,000	$S.F. = 0.9999 + 1.22484 \times 10^{-14}\,(v)^2$

SCALE FACTORS ALASKA ZONE 1

V	S.F.	V	S.F.	V	S.F.	V	S.F.
0	0.9999000						
1000	0.9999000	36000	0.9999159	71000	0.9999618	106000	1.00003
2000	0.9999000	37000	0.9999168	72000	0.9999635	107000	1.00004
3000	0.9999001	38000	0.9999177	73000	0.9999653	108000	1.00004
4000	0.9999002	39000	0.9999186	74000	0.9999671	109000	1.00004
5000	0.9999003	40000	0.9999196	75000	0.9999689	110000	1.00004
6000	0.9999004	41000	0.9999206	76000	0.9999708	111000	1.00005
7000	0.9999006	42000	0.9999216	77000	0.9999727	112000	1.00005
8000	0.9999008	43000	0.9999226	78000	0.9999746	113000	1.00005
9000	0.9999010	44000	0.9999237	79000	0.9999765	114000	1.00005
10000	0.9999012	45000	0.9999248	80000	0.9999784	115000	1.00006
11000	0.9999015	46000	0.9999259	81000	0.9999804	116000	1.00006
12000	0.9999017	47000	0.9999271	82000	0.9999824	117000	1.00006
13000	0.9999021	48000	0.9999282	83000	0.9999844	118000	1.00007
14000	0.9999024	49000	0.9999294	84000	0.9999865	119000	1.00007
15000	0.9999027	50000	0.9999306	85000	0.9999885	120000	1.00007
16000	0.9999031	51000	0.9999319	86000	0.9999906	121000	1.00007
17000	0.9999035	52000	0.9999331	87000	0.9999928	122000	1.00008
18000	0.9999040	53000	0.9999344	88000	0.9999949	123000	1.00008
19000	0.9999044	54000	0.9999357	89000	0.9999971	124000	1.00008
20000	0.9999049	55000	0.9999371	90000	0.9999993	125000	1.00009
21000	0.9999054	56000	0.9999384	91000	1.0000015	126000	1.00009
22000	0.9999059	57000	0.9999398	92000	1.0000037	127000	1.00009
23000	0.9999065	58000	0.9999412	93000	1.0000060	128000	1.00010
24000	0.9999070	59000	0.9999427	94000	1.0000083	129000	1.00010
25000	0.9999076	60000	0.9999441	95000	1.0000106	130000	1.00010
26000	0.9999083	61000	0.9999456	96000	1.0000129	131000	1.00011
27000	0.9999089	62000	0.9999471	97000	1.0000153	132000	1.00011
28000	0.9999096	63000	0.9999486	98000	1.0000177	133000	1.00011
29000	0.9999103	64000	0.9999502	99000	1.0000201	134000	1.00012
30000	0.9999110	65000	0.9999518	100000	1.0000226	135000	1.00012
31000	0.9999118	66000	0.9999534	101000	1.0000250	136000	1.00012
32000	0.9999125	67000	0.9999550	102000	1.0000275	137000	1.00013
33000	0.9999133	68000	0.9999567	103000	1.0000300	138000	1.00013
34000	0.9999142	69000	0.9999583	104000	1.0000326	139000	1.00013
35000	0.9999150	70000	0.9999600	105000	1.0000351	140000	1.00014

CORRECTION TO SCALE FACTOR (7th Decimal Place)

N \ V	0	25,000	50,000	75,000	100,000	125,000	150,000
1,000,000	0	0	0	-1	-1	-2	-2
800,000	0	0	0	-1	-1	-1	-1
600,000	0	0	0	0	0	0	0
400,000	0	0	0	0	0	0	+1
200,000	0	0	0	0	+1	+1	+2

ZONE 1 SCALE FACTOR CORRECTION FOR LONG LINES

ΔV	Corr.	ΔV	Corr.	ΔV	Corr.
0	0				
1000	0	41000	17	81000	67
2000	0	42000	18	82000	69
3000	0	43000	19	83000	71
4000	0	44000	20	84000	72
5000	0	45000	21	85000	74
6000	0	46000	22	86000	76
7000	1	47000	23	87000	77
8000	1	48000	24	88000	79
9000	1	49000	25	89000	81
10000	1	50000	26	90000	83
11000	1	51000	27	91000	85
12000	1	52000	28	92000	87
13000	2	53000	29	93000	89
14000	2	54000	30	94000	90
15000	2	55000	31	95000	92
16000	3	56000	32	96000	94
17000	3	57000	33	97000	96
18000	3	58000	34	98000	98
19000	4	59000	36	99000	100
20000	4	60000	37	100000	102
21000	5	61000	38	101000	104
22000	5	62000	39	102000	106
23000	5	63000	41	103000	109
24000	6	64000	42	104000	111
25000	6	65000	43	105000	113
26000	7	66000	45	106000	115
27000	7	67000	46	107000	117
28000	8	68000	47	108000	119
29000	9	69000	49	109000	122
30000	9	70000	50	110000	124
31000	10	71000	52	111000	126
32000	10	72000	53	112000	128
33000	11	73000	55	113000	131
34000	12	74000	56	114000	133
35000	13	75000	58	115000	135
36000	13	76000	59	116000	138
37000	14	77000	61	117000	140
38000	15	78000	62	118000	143
39000	16	79000	64	119000	145
40000	16	80000	66	120000	147

NOTE: These values are based on the formula:

$$\text{Correction} = 1.0236 \times 10^{-15} \, (\Delta V)^2$$

The main portion of the Scale Factor tables on the preceding pages were based on the radius of curvature of the earth's surface at Kake, with a N value of about 575,000. If the N values of your survey differ greatly from this, then use the table at the bottom of the page to obtain a correction to be applied to the 7th decimal place.

PROBLEM: Near Juneau, at E = 760,000 N = 710,000, what is the scale factor? Do two ways.

Using the formula:

Using the tables:

PROBLEM: Near Sitka, at E = 710,000 N = 590,000, what is the scale factor? Do two ways.

Using the formula:

Using the tables.

SCALE FACTORS FOR SHORT LINES. Use the scale factor at the midpoint.

PROBLEM. Near Skagway, there is a line AB. Point A is at E = 720,000 N = 850,000. Line AB heads exactly grid east (grid azimuth = 90°) and has a geodetic length of 6000.000 meters. What are the coordinates of point B?

PROBLEM: Near Ketchikan, point A has coordinates E= 952,345.678 N =398,456.222. Line AB has a grid azimuth of 38° 23' 45" and a geodetic length of 3456.789 meters. What are the coordinates of point B?

SCALE FACTORS ON LONG LINES

Knowing the coordinates of the starting point of the line, and its grid azimuth and geodetic length, you can assume that the grid length will be just about the same as the geodetic length.

You can compute the approximate coordinates of the midpoint and of the end point, in the E, N system.

Then compute the v-coordinates for the beginning, midpoint, and end.

$$v = 0.8\,E + 0.6\,N - 1{,}000{,}000$$

You can now proceed in one of two ways. Use either method, but don't try to use both in some weird combination.

SIMPSON'S RULE

Knowing the v's of the three points, compute (or use the tables) the scale factors at all three points. Then:

$$\text{Scale factor for the line} = \frac{SF_1 + 4\,SF_m + SF_2}{6}$$

where:
1 & 2 are the ends
m is the midpoint

THE Δv METHOD

Using the v of the midpoint, compute (by formula or tables) the scale factor at the midpoint.

Using the v's of both ends, determine the difference (absolute value) of the v's for the entire line, not just to the midpoint.

Using the table of Δv corrections, add this correction to the scale factor at the midpoint to obtain the scale factor for the entire line.

PROBLEM: Point A is at E = 900,000.00 N = 500,000.00 (near Wrangell.) Line AB has a grid azimith of 20° 00' 00" and a geodetic length of 50,000.000 meters. What are the coordinates of point B? Solve this by both methods.

MAPPING ANGLES IN ZONE 1

The mapping angle in Zone 1 is called gamma (γ). Unlike the other zones in Alaska, there is no simple formula to calculate gamma.

If forced to compute gamma, you should probably use the calculator formulas developed by the National Geodetic Survey, which will soon be published. (The 1927 NAD programs have long been available, but to my knowledge, the 1983 versions are just now in the final stages.)

Some band-aid methods which might be used are:

From geodetic control information of nearby points, use their published gamma for the control point.

On U.S.G.S. maps, connect up the coordinate ticks on the top and on the bottom of the map to create, in effect a grid north line. See what angle this line cuts the true north-south lines of longitude.

Remember, for short lines: True Azimuth = Grid Azimuth + Gamma

SIGN OF THE MAPPING ANGLE

East of Longitude 133° 40' W. (Kake) or east of E = 818,585.5665, the mapping angle (gamma) will be positive, and the relation of true and grid north will be as shown below.

West of Longitude 133° 40' W., or at points with E coordinates less than 818,585.5665, gamma will be negative, and the angular relation below prevails.

CAUTION CAUTION WARNING WARNING

In the Transverse Mercator projections (like Alaska Zones 2-9) an exact formula (for all practical purposes) is:

$$\tan(\Delta\alpha) = \tan(\Delta\lambda) \sin \phi \qquad \text{where } \phi \text{ is the latitude}$$

Even though Zone 1 has the name Mercator in it (Oblique Mercator) this is an entirely different mathematical projection, and the Transverse Mercator does NOT apply, and should NOT be used.

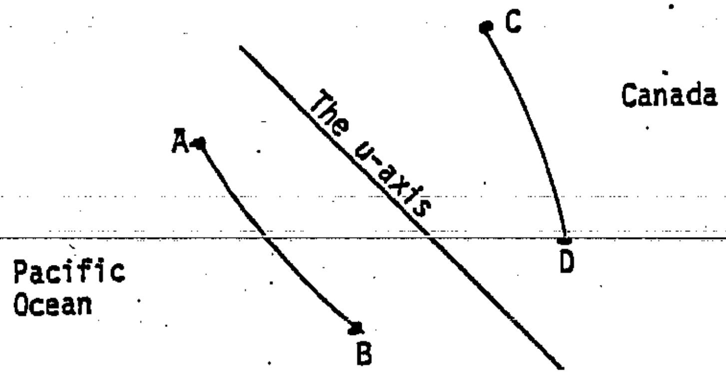
Surveyors who use this formula in Southeastern Alaska will be banished from the state forever.

SECOND TERM CORRECTIONS IN ZONE 1

We will now consider, for Zone 1, the arc-to-chord, T-t, 2nd term, or "J" corrections. Again, for simplicity, we'll call these corrections the J correctio

Lines which are really straight lines on the ground appear to curve when plotted on the Zone 1 grid.

Remember the u-axis? Well, lines on the Canadian side of the u-axis will bulge away from the axis and toward Canada. Lines on the ocean side of the axis will bulge away from the axis and toward the ocean. See sketch belo



In the Zone 1 system, all computations are normally made using the X,Y system. (E, N) For scale factors, it is necessary to compute the v coordinates. If you need to work with long lines, then it is also necessary to compute the u coordinates.

$$u = -0.6\,E + 0.8\,N + 7{,}000{,}000$$
$$v = 0.8\,E + 0.6\,N - 1{,}000{,}000$$

Remember that subscript 1 refers to where the theodolite is set up, and subscript 2 refers to the point sighted.

In decimal degrees: $$J^\circ = \frac{(u_2 - u_1)(v_2 + 2v_1)}{4.271 \times 10^{12}}$$

In seconds: $$J'' = \frac{(u_2 - u_1)(v_2 + 2v_1)}{1.1864 \times 10^{9}}$$

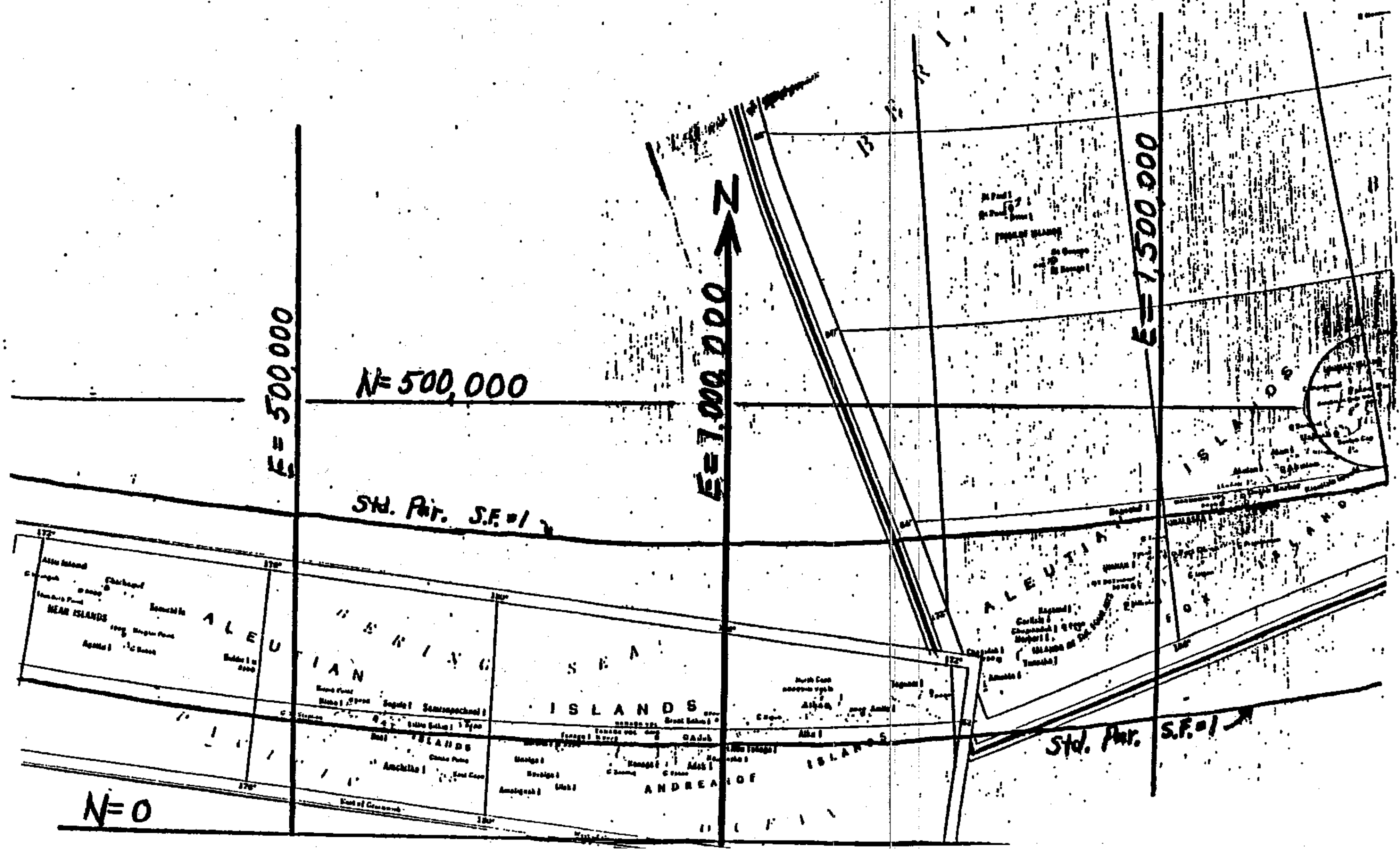
Note the almost exact similarity to the J formulas for zones 2-9. The denominators are slightly different because the average radius of curvature for the earth is slightly different in Southeastern Alaska from western Alaska.

True Azimuth of Line AB = Grid Azimuth of Line AB + Gamma + J (at point A)
(based on true north at point A)

Grid Angle (clockwise) = Field Angle + J_{back} - J_{ahead}

PROBLEM: Near Juneau, Point A is at E = 760,000 N = 710,000. Point B is at E = 740,000 N = 760,000. When sighting B, what is J° at A?

ALASKA ZONE 10



ALASKA ZONE 10

Alaska Zone 10 is a Lambert Conformal Conic projection, so much of the approach we used in the Transverse Mercator and the Oblique Mercator projections will not help us. Some things are familiar, however.

There is a central meridian. For Alaska Zone 10 it is at 176° W. This true north-south line becomes the direction of grid north.

There is a difference in longitude or $\Delta\lambda$ which is defined as:

$$\Delta\lambda = 176° - \text{west longitude of a point.}$$

NOTE: Zone 10 lies in both the western and eastern hemisphere. (Who said that "never the twain shall meet" ?) The extreme western part of the Aleutian Islands lies in (real) east longitudes. It is strongly suggested that if you are in this area, you convert to a "fake" western longitude. For example: Attu is really at about 172° E., but you can convert this to a fake 188° W.

Fake western longitude = 360° - the real eastern longitude.

PROBLEM: At Dutch Harbor, longitude 166° 30' W., what is $\Delta\lambda$?

PROBLEM: At Kiska,Longitude 177° 30' E., what is $\Delta\lambda$?

MAPPING ANGLE, WHEN LONGITUDE IS KNOWN

In Lambert projections, the mapping angle is known as theta (θ). If you know the difference in longitude $\Delta\lambda$, then you can easily compute the mapping angle.

$$\theta = 0.79692\ 23894\ 865\ \Delta\lambda$$ (usually rounded to 0.79692 23895)

If $\Delta\lambda$ is in decimal degrees, then θ will also be in decimal degrees.

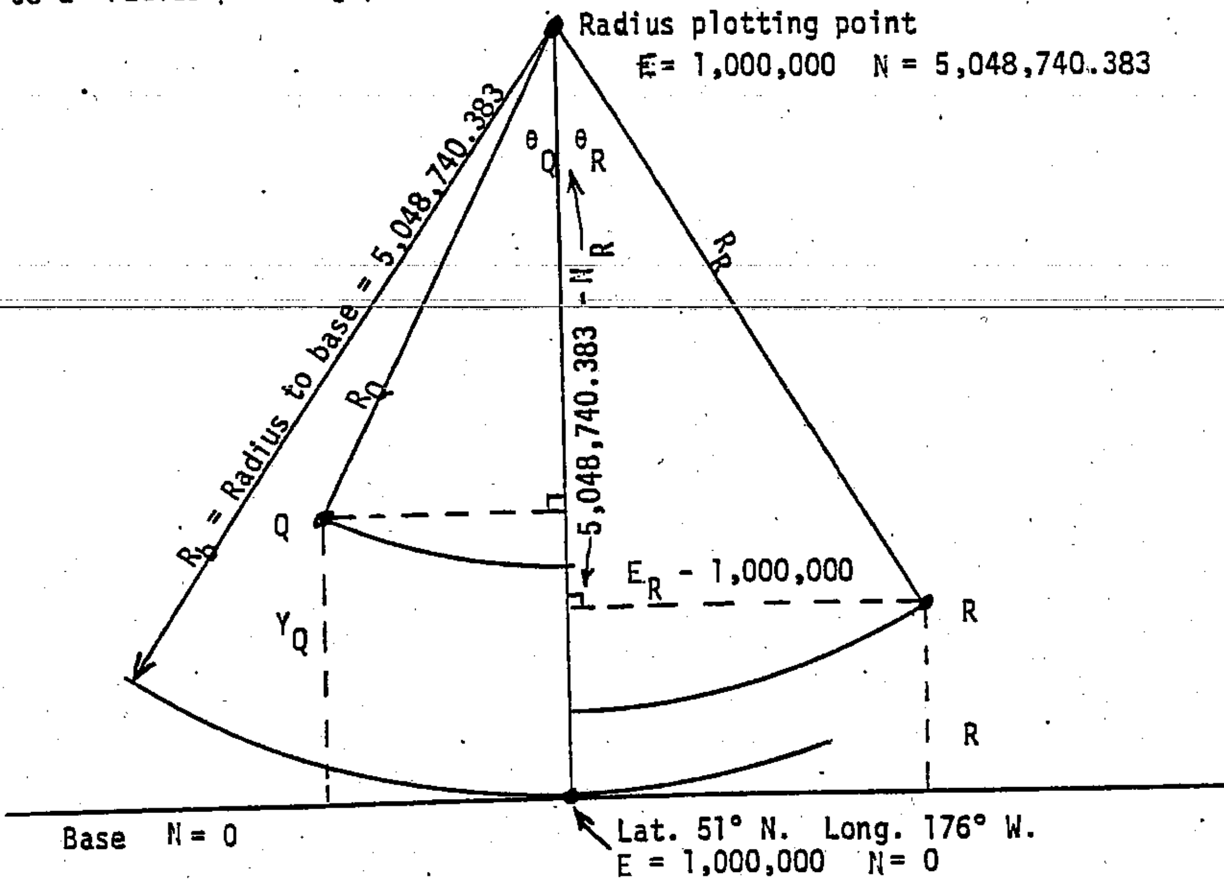
PROBLEM: (See above) What is the mapping angle at Dutch Harbor?

PROBLEM: (See above) What is the mapping angle at Kiska?

E, N, R, and R_b IN ZONE 10

Imagine that you were going to plot up a conic projection. There is a point at Lat. 51° N., Long. 176° W, which we will call E = 1,000,000 and N = 0.

Let's go due north from this point a distance of 5,048,740.38295 meters to a "radius plotting point." See sketch below.



Let's take a typical point R on the east side of the central meridian, and we will develop some mathematical relations. These will also apply to a typical point Q on the west side of the central meridian.

$$R^2 = (E-1,000,000)^2 + (5,048,740.383 - N)^2$$

$$\tan \theta = \frac{E - 1,000,000}{5,048,740.383 - N}$$

Note: Those of you who are adept at rectangular to polar conversions on your calculator can do this with one key

Remember that θ is the mapping angle, the relation between true north and grid north. We have already discussed this angle.

If you know both E and N, you can compute θ. Then, if you want to get the longitude, use:

$$\Delta\lambda = \frac{\theta}{0.79692\ 23895}$$

SCALE FACTORS IN ZONE 10

The scale factors are a function of latitude, and they are related to the value of R. There are two latitudes (51° 50' N. and 53° 50' N.) where the scale factor is exactly 1.0000000. Almost midway between them, at Lat. 52° 50' 13.9527" N. the scale factor is a minimum, at 0.9998481.

A polynomial series will allow you to compute the scale factor.

$$S.F. = A + B(R) + C(R)^2 + D(R)^3$$

On a calculator, it is usually simplest to "nest" this equation thus:

$$S.F. = A + R\ (\ B + R\ (\ C + R\ (D)))$$

For Zone 10 the values are:

$A = 1.38161\ 221$

$B = -1.76953\ 11 \times 10^{-7}$

$C = 2.42524\ 66 \times 10^{-14}$

$D = -8.24127\ 56 \times 10^{-22}$

Since this tends to get rather complicated, it is always good to check your calculator with a few "check" values.

For R = 4,700,000 the scale factor should be 1.0001062
For R = 4,800,000 the scale factor should be 0.9998722
For R = 5,000,000 the scale factor should be 1.0001424

The table on the next page gives values of the scale factor for various values of R.

PROBLEM: For a point of E = 1,300,000.00 and N = 250,000.00, what is the scale factor? Do two ways, both with the formula and with the tables on the next page.

ZONE 10 SCALE FACTORS AS A FUNCTION OF "R"

$$R^2 = (E - 1{,}000{,}000)^2 + (5{,}048{,}740.383 - N)^2$$

R	S.F.	R	S.F.
4650000	1.0003176	4855000	0.9998494
4655000	1.0002936	4860000	0.9998511
4660000	1.0002703	4865000	0.9998533
4665000	1.0002475	4870000	0.9998561
4670000	1.0002255	4875000	0.9998596
4675000	1.0002040	4880000	0.9998636
4680000	1.0001832	4885000	0.9998683
4685000	1.0001630	4890000	0.9998736
4690000	1.0001434	4895000	0.9998795
4695000	1.0001245	4900000	0.9998859
4700000	1.0001062	4905000	0.9998930
4705000	1.0000886	4910000	0.9999008
4710000	1.0000715	4915000	0.9999091
4715000	1.0000551	4920000	0.9999180
4720000	1.0000394	4925000	0.9999275
4725000	1.0000242	4930000	0.9999376
4730000	1.0000097	4935000	0.9999484
4735000	0.9999958	4940000	0.9999597
4740000	0.9999826	4945000	0.9999716
4745000	0.9999700	4950000	0.9999841
4750000	0.9999580	4955000	0.9999973
4755000	0.9999466	4960000	1.0000110
4760000	0.9999358	4965000	1.0000253
4765000	0.9999257	4970000	1.0000403
4770000	0.9999162	4975000	1.0000558
4775000	0.9999073	4980000	1.0000719
4780000	0.9998991	4985000	1.0000887
4785000	0.9998914	4990000	1.0001060
4790000	0.9998844	4995000	1.0001239
4795000	0.9998780	5000000	1.0001424
4800000	0.9998722	5005000	1.0001615
4805000	0.9998671	5010000	1.0001812
4810000	0.9998625	5015000	1.0002015
4815000	0.9998586	5020000	1.0002224
4820000	0.9998553	5025000	1.0002439
4825000	0.9998526	5030000	1.0002660
4830000	0.9998506	5035000	1.0002886
4835000	0.9998491	5040000	1.0003119
4840000	0.9998483	5045000	1.0003357
4845000	0.9998480	5050000	1.0003601
4850000	0.9998484		

ZONE 10 SCALE FACTOR CORRECTION FOR LONG LINES

Corrections (plus) to 7th decimal place

Δ N	Corr.	Δ N	Corr.	Δ N	Corr.
0	0				
1000	0	41000	17	81000	67
2000	0	42000	18	82000	69
3000	0	43000	19	83000	71
4000	0	44000	20	84000	72
5000	0	45000	21	85000	74
6000	0	46000	22	86000	76
7000	1	47000	23	87000	77
8000	1	48000	24	88000	79
9000	1	49000	25	89000	81
10000	1	50000	26	90000	83
11000	1	51000	27	91000	85
12000	1	52000	28	92000	87
13000	2	53000	29	93000	89
14000	2	54000	30	94000	90
15000	2	55000	31	95000	92
16000	3	56000	32	96000	94
17000	3	57000	33	97000	96
18000	3	58000	34	98000	98
19000	4	59000	36	99000	100
20000	4	60000	37	100000	102
21000	5	61000	38	101000	104
22000	5	62000	39	102000	106
23000	5	63000	41	103000	109
24000	6	64000	42	104000	111
25000	6	65000	43	105000	113
26000	7	66000	45	106000	115
27000	7	67000	46	107000	117
28000	8	68000	47	108000	119
29000	9	69000	49	109000	122
30000	9	70000	50	110000	124
31000	10	71000	52	111000	126
32000	10	72000	53	112000	128
33000	11	73000	55	113000	131
34000	12	74000	56	114000	133
35000	13	75000	58	115000	135
36000	13	76000	59	116000	138
37000	14	77000	61	117000	140
38000	15	78000	62	118000	143
39000	16	79000	64	119000	145
40000	16	80000	66	120000	147

NOTE: These values are based on the formula:

$$\text{Correction} = 1.0236 \times 10^{-15} \, (\Delta N)^2$$

ZONE 10 SCALE FACTOR FOR LONG LINES

Knowing the E and N coordinates of the beginning of the line, and the grid azimuth and geodetic length of the line, you can compute the approximate locations (E and N) of both the midpoint of the line, and also the end point of the line. To get the overall scale factor to use for the line, you can do this in one of two ways. Use either way, but do not try to combine them.

Simpson's Rule. Using the E and N values at the beginning, midpoint, and end, compute the R values for these three points. Then, use either the formula or the tables to determine the scale factors at these three points.

$$\text{Overall scale factor for the line} = \frac{SF_1 + 4\,SF_m + SF_2}{6}$$

The ΔN Method. This method comes in two versions, which I will call the "pretty good" method, and the "exact" method. For either version, use the E and N at the approximate midpoint, compute R at the midpoint, and using either the formula or the tables, compute the scale factor at the midpoint. Now, take a look at the difference in N coordinates between the beginning and the end of the line (use the absolute value of the difference) and call this ΔN. Using the Zone 10 Scale factor correction for long lines, add this correction to the scale factor at the midpoint.

"Pretty good" Scale factor for the line = S.F. at midpoint + ΔN correction

(The ΔN correction is based on the difference in Y values between the two ends.)

This version (above) works very well near the central meridian of the zone. If the zone is quite large in east-west extent, as Zone 10 Alaska is, then at locations far from the central meridian, there is a slight error. Let us compute a quantity called the "modified ΔY.

Modified ΔN = absolute value of [R at end of line - R at beginning of line

"Exact" Scale factor for the line = S.F. at midpoint + ΔN correction based on the modified Δ.

PROBLEM: Point A is at Zone 10 E = 200,000.00 N = 250,000.00. Line AB heads exactly grid N 40° W and has a geodetic length of 60,000.00 meters. What are the coordinates of Point B? Do three ways.

Simpson's Rule:

Pretty Good Δ

Exact Δ

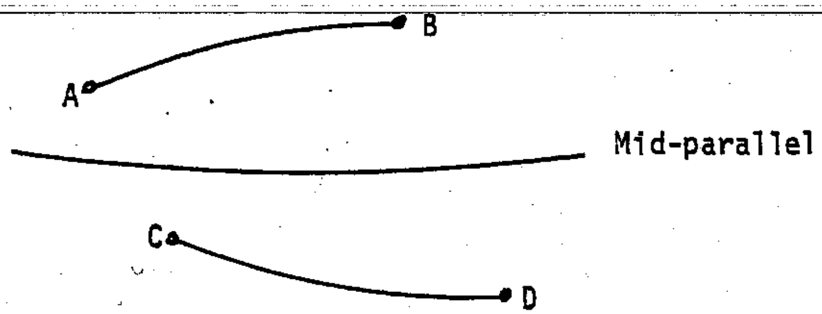
MAPPING ANGLES IN ZONE 10. (For short lines)

True geodetic azimuth = Grid azimuth + θ

This has been discussed before.

SECOND TERM CORRECTIONS IN ZONE 10

Lines which are really straight lines in the field, appear as curved lines when plotted on the Lambert grid. Imagine a true east-west line at about the mid-latitude of the zone (about halfway between the two standard parallels.) Let's call this the mid-parallel. When really straight lines are plotted on the grid, they bulge <u>away</u> from the mid-parallel. See sketch below.



Lines AB and also CD are really straight in the field, but they appear as above, when plotted on the Lambert grid.

This results in a corrective term known as arc-to-chord, T-t, 2nd term, or J.

The J term in degrees $J^\circ = \dfrac{E_1 - E_2}{1.422 \times 10^{12}} \left[N_1 - N_o + \dfrac{N_2 - N_1}{3} \right]$

The J term in seconds $J'' = \dfrac{E_1 - E_2}{3.950 \times 10^{8}} \left[N_1 - N_o + \dfrac{N_2 - N_1}{3} \right]$

Note: In both formulas above, N_o = 204,422.029 meters. (This is the N value for the mid-parallel at the central meridian.)

The above formulas work well near the central meridian (Long. 176° W.) If you are far from the central meridian, then, for ultra-precise work, you shoul make some modifications:

For $E_1 - E_2$ substitute $(E_1 - E_2) \cos \theta_1 + (N_1 - N_2) \sin \theta_1$ (Generally, the θ angle is so small that the cos is about 1.0

For $N_2 - N_1$ substitute $R_1 - R_2$

For $N_1 - N_o$ substitute $4{,}844{,}318.354 - R_1$

If you are taking a sight on a long line, the relation between the true geodetic azimuth and the grid azimuth is:

True geodetic azimuth of line AB (based on true N. at A) $=$ Grid Azim. of AB $+ \theta_{\text{at A}} + J_{\text{at A}}$

If you turn a field angle with either the backsight or foresight involving long lines, remember, for clockwise angles:

$$\text{Grid Angle} = \text{Field Angle} + J_{\text{backsight}} - J_{\text{ahead sight}}$$

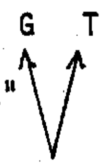
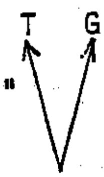
PROBLEM: Point A (theodolite) is at E = 1,600,000 N = 400,000.
Point B (target) is at E = 1,680,000 N = 420,000
What is the J angle at point A? Do both "pretty good" and exact methoc

SUMMARY

Formulas and tables have been presented here which should enable you to make plane coordinate calculations in any of the Alaska zones, without any reference to latitude and longitude. If you have grid coordinates of the starting point of a traverse, and also the grid coordinates of a suitable backsight, you should be able to run very long traverses and get coordinates of all points in the grid (plane coordinate) system.

Many of the corrections, which may seem complicated, actually are necessary only on long lines. Practically all of the most common work can be done using only the scale factors at the midpoints of the lines in a traverse. Don't be afraid of the plane coordinate system - use it.

ANSWERS TO PROBLEMS

Page 5	3123.822 meters
Page 6	23,445.241 + 0.013 = 23,445.254 meters 15,452.342 + 0.004 = 15,452.346 meters
Page 7	5431.370 + 0.000 = 5431.370 meters 3141.261 meters
Page 8	0.9998629 x 0.9999103 = 0.9997732 combined 765.258 meters, 1301.491 meters, 945.520 meters
Page 9	Grid Az. = 62° 55' 14" True Bearing = S 35° 55' 11" E Point B at E = 538,467.911 N = 1,031,285.575 Grid length = 22,360.680 meters Grid Az. = 333° 26' 05.82"
Page 11	E' = +64,376.543 meters E' = -84,012.655 meters Scale factor = 0.9999874
Page 14	Scale factor = 0.9999874 Scale factor = 1.0003427 or 1.0003428 Midpoint at E=529,000 N=1,501,732 S.F.=0.9999103, Grid L. = 3999. Point B at E = 529,999.821 N = 1,503,463.791
Page 15	Scale factor, either method = 1.0002770 Either method, S.F. = 1.0000938 Grid L. = 62,339.180 Point R at E = 405,166.761 N= 528,162.445
Page 16	S.F. = 0.9999110 Sea level area = 765.568 hectares Combined factor = 0.9996873 True surface area = 765.911 hectares
Page 17	+ 1° 36' - 1° 50'
Page 18	1° 19' 42.8"  1° 40' 37.2"  2° 09' 27.5" 
Page 21	J_A = + 0° 00' 11.89" J_B = - 0° 00' 12.40" True Az. A to B = 36° 19' 35.56" True Az. B to A = 216° 42' 26.18"
Page 22	120° 00' 19" 114° 34' 59.1"
Page 26	v = +34,000 meters v = -78,000 meters

Page 29	Juneau S.F. = 0.9999142 Sitka S.F. = 0.9999746 Skagway, midpoint v = +88,400 S.F. = 0.9999957 or 0.9999958 Grid L. = 5999.974 Point B at E = 725,999.974 N = 850,000.000 Ketchikan midpoint v = +2621.83 S.F. = 0.9999001 Grid L. = 3456.444 Point B at E = 954,492.443 N = 401,165.170
Page 30	Overall scale factor = 0.9999222 or 0.9999223 Grid L. = 49,996.115 Point B at E = 917,099.678 N = 546,980.980
Page 32	J_A = + 0° 00' 05.08"
Page 34	Dutch Harbor +9° 30' Kiska -6° 30' Dutch Harbor, mapping angle = +7° 34' 14.75" Kiska, mapping angle = -5° 10' 47.98"
Page 36	R = 4,808,108.699 Scale Factor = 0.9998641
Page 39	Simpson's Rule S.F. = 0.9998495 Approx. ΔN = 45,962.67 S.F. = 0.9998480 + 22 (7th) = 0.9998502 Exact ΔN = 38,779.50 S.F. = 0.9998480 + 16 (7th) = 0.9998496 Using 0.9998495, Grid Length = 59,990.970 Point B at E = 161,438.548 N = 295,955.749
Page 41	Pretty good: J_A = - 0° 00' 40.96" Exact J_A = - 0° 00' 33.17"

NAD 83 GEODETIC AND STATE PLANE COORDINATES

QIDQSN	STATION NAME	LATITUDE	LONGITUDE	NORTHING METERS*	EASTING METERS*	ZONE	CONVERGENCE	SCALE FACTOR	HEIGHT (M)	GEOID HT(M)
551321130010	A	55 48 6.21463	132 09 38.19007	462593.702	912679.269	AK 1	1 15 18.07	0.9953203	38 SC	- 5.60
551313220002	A POINT-ANN 1959 AZ MK	55 03 27.99213	131 36 20.54917	380908.080	949774.019	AK 1	1 42 47.44	0.9954023	35 SC	- 5.61
551313220009	A POINT-FOREST 1959 AZ MK	55 05 9.88978	131 35 16.66963	384084.013	950807.420	AK 1	1 43 39.83	0.9953985	11 SC	- 2.41
551341410001	AATS 1922	55 55 47.40236	134 16 6.72486	475949.014	781232.920	AK 1	-0 29 55.13	0.9954033		
551331330016	ABE	55 33 6.78748	133 26 50.42020	433835.544	832461.270	AK 1	0 11 20.05	0.9954130	2 SC	- 3.66
551323140018	ABE 1924	55 24 54.16304	132 40 16.33362	419074.797	881437.896	AK 1	0 49 59.44	0.9953846	2 SC	- 5.59
551304340007	ABE 1931	55 42 49.56371	130 53 29.01010	455293.853	992256.904	AK 1	2 18 13.18	0.9953839	3 SC	- 4.90
551313140010	ABIDE 1951	55 23 45.28662	131 44 45.35131	418188.208	939811.428	AK 1	1 35 51.08	0.9953638	9 SC	- 3.86
551332210008	ABLE 1907	55 13 58.85595	133 05 45.61522	398551.534	854830.278	AK 1	0 28 59.19	0.9954538	2 SC	- 6.47
551303330010	ABLE 1933	55 04 54.99432	130 55 17.86150	385104.100	993154.140	AK 1	2 16 30.12	0.9954060	6 SC	- 3.86
551332210009	ABLE ECC 1958	55 13 58.51864	133 05 45.56293	398541.135	854831.285	AK 1	0 28 59.24	0.9954538	9.	- 4.58
551311410010	ACT 1891	55 58 12.50379	131 15 16.90989	482894.191	968547.799	AK 1	2 00 20.70	0.9953522	4 SC	- 7.10
541304130018	ADA 1933	54,45 10.31273	130 37 57.00065	349359.495	1013119.591	AK 1	2 30 39.09	0.9954390	4 SC	- 3.71
551332420013	ADRIAN 1907	55 19 10.30298	133 17 50.07322	408071.098	842032.327	AK 1	0 18 56.33	0.9954531		
551321430005	AGE	55 51 40.97926	132 22 59.00351	468935.827	898673.502	AK 1	1 04 14.35	0.9953131	2 SC	- 6.20
541311140002	AGE 1932	54 55 42.34546	131 13 5.71349	367357.413	974915.340	AK 1	2 01 53.19	0.9954148	2 SC	- 7.06
541304130010	AGE 1933	54 45 30.81030	130 39 56.04375	349898.901	1010974.797	AK 1	2 29 1.81	0.9954377	9 SC	- 3.39
551332140005	AGUEDA 1907	55 27 2.04818	133 14 31.68906	422645.130	845423.162	AK 1	0 21 36.26	0.9954176	3.	- 6.02
551304320011	AID 1891	55 33 37.51022	130 52 35.98008	438314.132	993865.725	AK 1	2 18 52.45	0.9953869	6 SC	- 2.59
551331420042	AID 1904	55 48 23.52503	133 19 51.14010	462146.496	839637.514	AK 1	0 17 1.28	0.9953508	3 SC	- 7.10
541304240011	AID 1933	54 43 39.77108	130 40 14.12468	346462.615	1010801.445	AK 1	2 28 46.78	0.9954402	7 SC	- 2.37
551331410066	AIKENS 1953	55 54 1.03938	133 15 41.62766	472581.794	843901.218	AK 1	0 20 26.86	0.9953297	7 SC	- 2.37
551331410070	AIKENS ROCK DAYBEACON 1953	55 54 1.01415	133 15 41.80377	472580.998	843898.177	AK 1	0 20 26.72	0.9953297	10 SC	- 3.34
551331230006	ALBERTO 1907	55 31 37.49226	133 11 36.21947	431162.802	848433.730	AK 1	0 23 59.48	0.9953971	6 SC	- 2.18
551334140010	ALCOA 1946	55 56 36.59800	133 39 37.58415	477304.890	819065.820	AK 1	0 00 30.29	0.9953458		
551334140009	ALCOA MINING CO TANK	55 56 53.33071	133 39 54.31309	477821.046	818776.773	AK 1	0 00 16.23	0.9953452		
551331410059	ALDER	55 55 12.21308	133 20 27.43567	474750.829	838947.769	AK 1	0 16 28.65	0.9953304	4 SC	- 6.68
551303230021	ALDER 1933	55 07 1.17489	130 44 8.17125	389478.419	1004804.994	AK 1	2 25 40.01	0.9954113	10 SC	- 2.50
551331130005	ALDER 1952	55 51 40.78118	133 12 4.05573	468279.168	847693.531	AK 1	0 23 28.55	0.9953335	8 SC	- 2.27
551331410065	ALDER 2 1922	55 55 12.21077	133 20 27.48997	474750.754	838946.831	AK 1	0 16 28.61	0.9953304	6 SC	- 2.30
551331410031	ALONG 1953	55 55 56.82799	133 16 2.07211	476151.549	843526.696	AK 1	0 20 9.26	0.9953244	3 SC	- 3.64
551323140022	ALPHA 1953	55 28 32.94042	132 38 12.66310	425855.182	883501.781	AK 1	0 51 40.65	0.9953723	3.	- 4.34
551311440015	AM 1891	55 56 41.54612	131 27 53.05261	479652.583	955590.822	AK 1	1 49 54.36	0.9953374	4 SC	- 4.62
541324420004	AMERICAN 1925	54 50 38.87530	132 47 28.54486	355568.844	874684.688	AK 1	0 44 19.45	0.9955162	2 SC	- 6.08
551304320009	AMES 1931	55 33 1.45848	130 50 2.49165	437311.844	996586.971	AK 1	2 20 58.58	0.9953903	2 SC	- 4.81
541321420005	ANCHOR 1909	54 49 51.37299	132 20 27.89360	354567.946	903499.452	AK 1	1 06 34.25	0.9954762	2 SC	- 4.38
551311440003	ANCHOR 1930	55 57 57.28384	131 23 45.50332	482126.567	959780.001	AK 1	1 53 19.76	0.9953416	2 SC	- 6.17
541311140006	ANCHOR 1932	54 55 51.20657	131 14 1.77518	367595.489	973912.575	AK 1	2 01 7.21	0.9954145	2 SC	- 6.74
551303230013	AND 1933	55 04 19.55970	130 43 7.81948	384542.384	1006081.207	AK 1	2 26 28.74	0.9954145		
551312340015	ANGLE POINT LIGHT	55 14 19.48590	131 25 36.77709	401350.182	960490.882	AK 1	1 51 36.84	0.9953819	8 SC	- 3.13
551334210016	ANGUILLA 1907	55 38 54.21517	133 32 33.45740	444538.258	826454.504	AK 1	0 06 31.91	0.9953997	2 SC	- 5.38
551313120012	ANN 1910	55 16 26.43156	131 35 23.92496	404941.403	950050.747	AK 1	1 43 33.61	0.9953771	4.	- 3.78
551321330001	ANN 1911	55 32 1.81262	132 23 39.77780	432553.648	898641.567	AK 1	1 03 42.16	0.9953543	38 SC	- 5.60
551313220003	ANN 1959	55 03 25.32817	131 36 22.35455	380824.982	949744.590	AK 1	1 42 45.96	0.9954024	2 SC	- 2.62
561323320003	ANNE 1966	55 59 58.82901	132 46 58.59225	483898.672	873556.774	AK 1	0 44 18.63	0.9952996	9 SC	- 2.75
551331420037	ANON 1914	55 45 37.60106	133 20 12.46605	457026.128	839292.711	AK 1	0 16 44.65	0.9953601		

* For conversion of meters to U.S. Survey Feet multiply the meters by 39.37/12.0which is 3.28083333333 to 12 significant figures

* For conversion of meters to International Feet multiply the meters by 100.0/30.48 which is 3.28083989501 to 12 significant figures

NOAA - NOS - C&GS
NATIONAL GEODETIC SURVEY
September 1986

Geodetic Control Diagram

FAIRBANKS

NAD 83 GEODETIC AND STATE PLANE COORDINATES

QIDQSN	STATION NAME	LATITUDE	LONGITUDE	NORTHING METERS*	EASTING METERS*	ZONE	CONVERGENCE	SCALE FACTOR	HEIGHT (M)	GEOID HT(M)
641523330001	CAMEL	64 06 28.83427	152 55 12.25665	1129128.854	357719.974	AK 4	-2 37 38.59	1.0001478	1070.	10.71
				1126312.419	552631.529	AK 5	0 58 17.57	0.9999339		
661572220001	CAMP 1954	66 03 1.73056	157 02 13.87033	1342752.879	543624.131	AK 6	0 52 47.76	0.9999233	86.	6.91
651541140001	CANOE E BASE 1954	65 55 11.78991	154 07 45.59219	1327869.366	494109.943	AK 5	-0 07 5.07	0.9999004	289.	8.01
651541410001	CANOE W BASE 1954	65 54 15.09626	154 15 22.65434	1326131.292	488320.646	AK 5	-0 14 2.26	0.9999017	108.	7.92
651472340001	CARIB USGS 1953	65 11 31.51198	147 29 53.06487	1247547.471	429847.673	AK 3	-1 21 35.59	0.9999602	773.	10.67
661503140001	CARIBOU 1955	66 22 44.23665	150 41 24.13960	1379212.812	469138.175	AK 4	-0 37 56.03	0.9999117	971.	9.53
671482130001	CARO ET	67 15 48.32114	148 09 28.46270	1478846.160	579464.081	AK 4	1 41 56.53	0.9999773	925.	8.75
641474420005	CE 314 U OF A	64 51 20.90096	147 49 8.48691	1210465.374	413742.153	AK 3	-1 38 48.32	0.9999911	157.82	10.96
671471410001	CHAN ET	67 57 58.09121	147 20 45.03424	1556647.616	443641.905	AK 3	-1 14 51.28	0.9999389	1861.	10.64
651472320001	CHATHAM 1941	65 03 34.10205	147 22 22.94956	1232632.802	435380.532	AK 3	-1 14 42.15	0.9999511	708.	10.78
661531430001	CHEB ET	66 49 50.36376	153 24 23.10723	1429533.729	526069.001	AK 5	0 32 44.55	0.9999083	630.	8.81
641474130010	CHENA EAST BASE 1941	64 50 55.35199	147 44 23.76365	1209568.991	417470.077	AK 3	-1 34 30.20	0.9999834	133.25	10.97
641481120001	CHENA GLO USGS 1910	64 48 0.41443	148 00 41.71505	1204501.048	594483.242	AK 4	1 47 57.49	1.0000093	397.0	11.08
641474420009	CHENA W BASE	64 51 20.78993	147 51 52.16593	1210524.682	411586.523	AK 3	-1 41 16.52	0.9999957	141.37	10.96
				1210930.831	601261.537	AK 4	1 55 59.93	1.0000255		
661574320001	CIRCLE 1954	66 32 8.50882	157 46 54.98494	1396536.677	509691.836	AK 6	0 12 0.10	0.9999011	536.	6.69
641492140001	CLEAR NORTH BASE 1942	64 22 29.05432	149 07 47.95681	1155885.793	541994.939	AK 4	0 47 4.02	0.9999216	143.	11.97
641492310002	CLEAR S BASE	64 13 30.82172	149 15 54.97160	1139138.297	535657.784	AK 4	0 39 41.90	0.9999156	215.71	13.06
671552240001	CLIFF ET	67 09 29.20190	155 13 3.44858	1466440.956	447240.555	AK 5	1 07 19.79	0.9999341	1032.	8.55
641483220001	COAL	64 03 36.72919	148 34 22.59081	1121317.499	569666.748	AK 4	1 17 0.02	0.9999594	1271.	14.12
661502130001	COAL 1955	66 15 27.55695	150 12 44.35669	1365533.671	490457.938	AK 4	-0 11 39.67	0.9999011	847.	10.04
651534420001	CONE 1954	65 50 58.66877	153 48 35.75506	1320037.088	508679.893	AK 5	0 10 24.36	0.9999009	652.	8.26
641523330002	CORNER	64 01 38.65417	152 57 23.08224	1117298.929	551007.735	AK 5	0 56 17.55	0.9999318	679.	10.78
671572220001	COSMOS USE 1955	67 00 48.05018	157 03 42.68139	1450089.556	540893.935	AK 6	0 51 49.19	0.9999205	951.	6.71
641521210001	COSNA 1942	64 38 49.43367	152 05 8.33683	1187337.011	591480.403	AK 5	1 43 48.34	1.0000024	735.	10.32
				1187595.264	400336.025	AK 4	-1 53 5.74	1.0000216		
651504340001	COUNT	65 41 10.76343	150 56 58.57126	1302145.949	456360.285	AK 4	-0 51 55.41	0.9999233	1682.	10.71
651541220001	COY 1954	65 34 55.59737	154 03 29.46648	1290198.839	497315.230	AK 5	-0 03 10.73	0.9999001	610.	8.55
671521340001	CRAG 1955	67 38 39.10340	152 24 57.10875	1520990.468	567254.217	AK 5	1 27 54.46	0.9999553	1248.	9.05
651474230001	CREEK	65 34 36.94559	147 39 56.13334	1290637.277	423138.303	AK 3	-1 30 59.85	0.9999723	356.	10.39
641481340001	CRESCENT 1942	64 40 15.33333	148 25 5.34664	1189558.158	575527.668	AK 4	1 25 47.44	0.9999698	306.	11.38
671522120001	CREVICE 1955	67 22 0.40890	152 00 29.09640	1490566.670	585555.718	AK 5	1 50 19.05	0.9999896	264.	9.07
				1490589.042	413750.186	AK 4	-1 51 12.77	0.9999910		
671522120002	CROP 1955	67 20 23.72205	152 06 4.16186	1487447.506	581650.727	AK 5	1 45 8.50	0.9999816	716.	9.05
				1487727.763	409652.415	AK 4	-1 56 20.73	0.9999999		
671572430002	CROSS ET	67 20 30.68622	157 24 43.01072	1486534.282	525287.296	AK 6	0 32 33.61	0.9999078	914.	5.88
651523320001	CUB 1954	65 01 3.51641	152 48 42.85007	1227793.819	556003.963	AK 5	1 04 37.07	0.9999384	231.	9.89
661503210001	CURKY 1955	66 08 47.05801	150 32 24.63890	1353218.354	475616.757	AK 4	-0 29 38.54	0.9999073	881.	10.35
671573140001	CUTLER USE 1955	67 26 36.72047	157 41 32.70477	1497785.715	513170.495	AK 6	0 17 2.59	0.9999021	1136.	5.66
661564440001	DAHL ET	66 56 39.56807	156 54 21.36052	1442504.739	547825.366	AK 6	1 00 24.11	0.9999280	74.	6.79
661562420001	DAKLI 1954	66 22 14.52927	156 20 23.58785	1379108.225	574266.829	AK 6	1 31 15.58	0.9999675	1140.	7.22
661493130001	DALL 1955	66 21 45.00676	149 39 11.91958	1377251.034	515515.946	AK 4	0 19 3.37	0.9999029	792.	9.60
661573410001	DAVIS 1954	66 23 52.59397	157 48 39.87019	1381172.509	508443.356	AK 6	0 10 23.24	0.9999009	609.	6.72
671511320001	DEADMAN ET	67 33 3.02302	151 16 5.46523	1510272.533	445944.659	AK 4	-1 10 19.59	0.9999357	1259.	9.28

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NOAA – NOS – C&GS
NATIONAL GEODETIC SURVEY
September 1986

Geodetic Control Diagram

FAIRBANKS

NAD 83 GEODETIC AND STATE PLANE COORDINATES

QIDQSN	STATION NAME	LATITUDE	LONGITUDE	NORTHING METERS*	EASTING METERS*	ZONE	CONVERGENCE	SCALE FACTOR	HEIGHT (M)	GEOID HT(M)
671503440001	DEE ET	67 25 45.42537	150 55 50.69600	1496463.199	460123.104	AK 4	-0 51 34.09	0.9999195	1127.	9.37
671543310001	DEER ET	67 08 21.34087	154 47 15.90691	1464038.631	465839.181	AK 5	-0 43 33.18	0.9999143	536.	8.82
651494320001	DERMOTT 1953	65 32 52.05187	149 46 10.89908	1286390.934	510640.720	AK 4	0 12 34.74	0.9999014	538.	11.24
651541420001	DIAN 1954	65 51 33.68479	154 15 54.76588	1321133.989	487893.047	AK 5	-0 14 31.27	0.9999018	98.	7.96
641474430001	DITCH 1941	64 50 9.62555	147 54 34.95856	1208385.698	409376.213	AK 3	-1 43 42.90	1.0000005	270.	11.00
				1208656.469	599190.676	AK 4	1 53 31.42	1.0000204		
661563130001	DIVISION 1954	66 20 41.49423	156 40 56.14646	1375862.513	559013.025	AK 6	1 12 25.38	0.9999426	519.	7.08
641471240001	DORAN 1941	64 43 34.36966	147 12 53.97417	1195334.149	442104.625	AK 3	1 05 55.40	0.9999410	247.	11.27
651484440001	DROP 1953	65 56 54.12842	148 54 14.05991	1331468.360	549861.451	AK 4	1 00 3.42	0.9999304	244.	10.40
661513230001	DUMMY	66 00 4.00495	151 45 1.70905	1338022.497	420539.849	AK 4	-1 35 57.24	0.9999773	770.	9.73
651474320001	DUNCAN	65 32 1.69491	147 51 47.98917	1286086.820	413873.005	AK 3	-1 41 46.02	0.9999908	769.	10.62
671492210001	EAST ET	67 14 17.17750	149 01 25.61878	1475175.808	542159.986	AK 4	0 54 0.73	0.9999217	1052.	9.27
661563420001	EASY 1954	66 15 15.51442	156 50 22.57427	1365627.951	552154.655	AK 6	1 03 43.86	0.9999333	856.	6.96
641551110001	EC 10001 BLM 1975	64 59 9.38345	155 02 28.01590	1224137.653	450865.658	AK 5	-0 56 36.53	0.9999205	758.	9.08
651543330001	EC 10002 BLM 1975	65 05 2.64620	154 58 58.39140	1235032.195	453783.667	AK 5	-0 53 29.12	0.9999261	442.	8.99
651552210001	EC 10003 BLM 1975	65 11 33.81487	155 00 35.14528	1247164.484	452713.712	AK 5	-0 54 59.77	0.9999274	497.	8.69
651543430001	EC 10004 BLM 1975	65 16 35.33425	154 59 13.04124	1256484.159	453927.710	AK 5	-0 53 47.41	0.9999260	659.	8.39
651543430002	EC 10005 BLM 1975	65 20 54.29088	154 57 18.78023	1264480.089	455530.720	AK 5	-0 52 5.42	0.9999242	458.	8.16
651543440001	EC 10006 BLM 1975	65 26 50.34224	154 56 38.70337	1275497.761	456214.146	AK 5	-0 51 31.44	0.9999235	424.	7.94
651544320001	EC 10007 BLM 1975	65 31 55.36475	154 51 46.34672	1284889.309	460109.853	AK 5	-0 47 7.41	0.9999195	955.	7.95
651544220001	EC 10008 BLM 1975	65 32 3.73593	154 35 19.43789	1285002.421	472785.305	AK 5	-0 32 9.14	0.9999091	766.	8.19
651542230001	EC 10009 BLM 1975	65 02 5.45269	154 13 4.27733	1229203.147	489737.017	AK 5	-0 11 51.00	0.9999013	673.	9.38
651542330001	EC 10010 BLM 1975	65 01 25.75645	154 23 38.35958	1228014.048	481431.875	AK 5	-0 21 25.72	0.9999042	762.	9.29
651543230001	EC 10011 BLM 1975	65 02 36.90405	154 38 38.28346	1230313.935	469673.437	AK 5	-0 35 1.84	0.9999113	1093.	9.22
651543320001	EC 10012 BLM 1975	65 03 47.68271	154 49 16.06377	1232602.325	461359.140	AK 5	-0 44 40.51	0.9999183	868.	9.09
641534420001	EC 10013 BLM 1975	64 47 12.60465	153 51 25.28623	1201544.575	506797.989	AK 5	0 07 45.68	0.9999006	261.	9.69
641531440001	EC 10014 BLM 1975	64 52 36.79322	153 28 40.10628	1211677.942	524745.346	AK 5	0 28 22.06	0.9999075	417.	9.70
651522440001	EC 10015 BLM 1975	65 25 17.75374	152 28 15.43436	1273163.665	570982.086	AK 5	1 23 26.02	0.9999617	616.	9.82
651522430001	EC 10016 BLM 1975	65 17 32.31683	152 24 15.78342	1258830.039	574436.757	AK 5	1 26 58.58	0.9999678	535.	9.91
641531110001	EC 10017 BLM 1975	64 57 44.18315	153 05 16.14420	1221405.477	543087.884	AK 5	0 49 35.31	0.9999227	212.0	9.82
671512430001	EC 10120 1975	67 17 14.32520	151 27 0.53237	1481061.583	437502.963	AK 4	-1 20 15.85	0.9999478	901.	9.07
671512130001	EC 10121 1975	67 16 44.01449	151 11 49.78559	1479890.450	448386.542	AK 4	-1 06 15.41	0.9999326	980.	9.15
671503430001	EC 10122 1975	67 16 44.58937	150 58 15.52640	1479738.063	458137.556	AK 4	-0 53 44.31	0.9999214	1495.	9.20
671512120001	EC 10123 1975	67 20 4.86718	151 01 20.73459	1485976.843	456021.798	AK 4	-0 56 36.53	0.9999237	1689.	9.27
671512110001	EC 10124 1975	67 22 32.39597	151 03 23.37404	1490570.764	454634.361	AK 4	-0 58 30.75	0.9999252	1545.	9.31
671512420001	EC 10125 1975	67 22 18.61865	151 21 52.29330	1490402.027	441399.645	AK 4	-1 15 34.28	0.9999420	1497.	9.18
671513130001	EC 10126 1975	67 21 46.35672	151 42 39.56430	1489771.594	426495.795	AK 4	-1 34 45.29	0.9999661	1304.	9.11
671511340001	EC 10127 1975	67 38 8.79669	151 25 52.52525	1519893.877	439213.552	AK 4	-1 19 25.12	0.9999452	1131.	9.16
671514220001	EC 10128 1975	67 33 54.17372	151 35 19.36998	1512171.433	432325.206	AK 4	-1 28 6.69	0.9999560	1444.	9.19
671514230002	EC 10129 1975	67 32 57.47733	151 38 39.66550	1510477.452	429909.064	AK 4	-1 31 11.22	0.9999601	1170.	9.19
671524220001	EC 10130 1975	67 32 49.11575	152 33 14.47074	1510007.724	561642.711	AK 5	1 20 11.06	0.9999465	1370.	9.15
671524330001	EC 10131 1975	67 33 37.39353	152 57 10.74748	1511161.073	544610.981	AK 5	0 58 3.91	0.9999243	1439.	9.21
671523410003	EC 10132 1975	67 27 47.77213	152 52 15.55147	1500393.600	548301.646	AK 5	1 02 34.13	0.9999285	1672.	9.22
671523430001	EC 10133 1975	67 21 41.50536	153 00 1.83241	1488953.976	542943.553	AK 5	0 55 20.99	0.9999226	1366.	9.17
671523120001	EC 10134 1975	67 22 3.15734	152 37 31.46295	1489932.725	559043.266	AK 5	1 16 7.59	0.9999426	1377.	9.11

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NOAA - NOS - C&GS
NATIONAL GEODETIC SURVEY
January 1987

Geodetic Control Diagram

WESTERN ALEUTIAN ISLANDS

NAD 83 GEODETIC AND STATE PLANE COORDINATES

QIDQSN	STATION NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	NORTHING METERS*	EASTING METERS*	ZONE	CONVERGENCE	SCALE FACTOR	ELEV. (M)	GEOID HT(M)
511764110032	30059 TOPOCOM	51 55 50.57786	176 33 22.09114	103711.451	961748.160	AK10	-0 26 35.51	0.9999720	6.	4.91
511764110031	30059 TOPOCOM RM 1 ANT	51 55 51.03973	176 33 22.05942	103725.720	961748.885	AK10	-0 26 35.49	0.9999720	11.	4.92
511764130021	9 NORTH 1958	51 51 10.34743	176 39 11.52388	95354.258	954995.657	AK10	-0 31 13.98	0.9999935	3 SC	4.32
511764130009	9 SOUTH 1958	51 51 11.15413	176 39 8.70636	95131.457	955047.561	AK10	-0 31 11.74	0.9999941	3 SC	4.30
521854340020	A 7 USE 1944	52 43 49.87541	185 54 59.01067	238669.409	332325.472	AK10	-7 54 9.34	0.9998498	4 SC	6.43
511814110012	A STATION-WILLIAM 1948	51 59 0.98594	181 31 50.67754	124055.763	620411.349	AK10	-4 24 27.26	0.9999580	123 SC	5.52
521822330023	A-AIR PHOTO CONTROL	52 03 40.48100	182 23 55.87320	137601.892	561745.291	AK10	-5 05 57.80	0.9999390		
511771140003	ABE 1943	51 53 41.42908	177 12 5.35720	100263.042	917296.309	AK10	-0 57 26.97	0.9999820	5.0	4.46
511764120014	ABE WW	51 50 35.81538	176 30 39.15225	93960.383	964792.089	AK10	-0 24 25.66	0.9999970		
521863110005	ABLE 1946	52 22 49.67236	186 31 39.61177	205908.568	285771.066	AK10	-8 23 23.05	0.9998796	3.	4.27
511792120014	ABOVE 1952	51 18 7.73505	179 06 48.88245	38325.731	782800.666	AK10	-2 28 52.61	1.0002020	11.	- 2.12
521742210008	ACE	52 08 0.74669	174 02 57.66724	127941.874	1133540.951	AK10	1 33 16.25	0.9999229		
511774310004	ACE 1943	51 40 48.94958	177 51 24.81608	77355.560	871573.579	AK10	-1 28 47.28	1.0000496	15.0	2.14
521742340005	ACE 1943	52 12 57.83286	174 27 25.32018	136443.347	1105438.836	AK10	1 13 46.64	0.9999064	267.	5.12
511783430011	ACE 1944	51 20 36.87469	178 59 25.63103	42567.168	791653.196	AK10	-2 22 59.37	1.0001832	6.0	- 1.21
521743320004	ACK	52 05 44.02596	174 48 46.58655	122576.224	1081341.870	AK10	0 56 45.58	0.9999311		
511764140005	ACORN 1955	51 58 18.16071	176 43 15.46443	108373.151	950457.289	AK10	-0 34 28.38	0.9999611	2 SC	5.02
521864130002	ACRE USN 1943	52 50 54.85217	186 45 9.73798	259749.346	278377.242	AK10	-8 34 8.66	0.9998481	2 SC	5.49
521863110010	ACROSS 1945	52 25 21.16059	186 34 10.03414	211035.854	283642.529	AK10	-8 25 22.92	0.9998741	286.	4.63
521752220004	AD ROCK	52 04 46.75731	175 01 52.40359	120582.185	1066409.169	AK10	0 46 19.34	0.9999347		
511764140001	ADAK NAVAL STA RADIO MAST	51 53 56.84592	176 39 51.86575	100259.765	954268.870	AK10	-0 31 46.13	0.9999808		
511764420010	AGA USN 1933	51 47 55.83942	176 48 43.96082	89207.443	943969.861	AK10	-0 38 50.17	1.0000106	67.	3.75
511771210001	AGAT 1943	51 43 56.69695	177 07 8.13034	82101.315	922697.761	AK10	-0 53 30.11	1.0000319	18.0	3.05
521861320002	AGAT 1945	52 29 56.68696	186 15 42.00791	216442.325	305570.311	AK10	-8 10 39.91	0.9998654	208 SC	5.57
521822330002	AGE USE 1943	52 00 26.79169	182 24 44.58648	131722.073	560287.786	AK10	-5 06 36.62	0.9999520	123.	2.80
511814410001	AIR PHOTO CONTROL POINT 1948	51 59 18.72651	181 51 25.59365	126376.073	598104.878	AK10	-4 40 3.58	0.9999568	54 SC	4.47
521813330001	AIR PHOTO CONTROL POINT 1948	52 02 27.97265	181 54 20.57134	132478.042	595257.144	AK10	-4 42 23.03	0.9999438	11 SC	4.32
521822330013	AIR PHOTO CONTROL POINT 1948	52 02 47.91194	182 29 9.80092	136518.974	555642.431	AK10	-5 10 7.99	0.9999424	108 SC	2.68
511821440037	AIR USE 1943	51 59 23.77332	182 28 11.02940	129929.345	558471.498	AK10	-5 07 45.51	0.9999564	4	2.74
521854310011	AIR USE 1943	52 42 40.62315	185 51 30.93049	236013.924	335900.105	AK10	-7 51 23.52	0.9998505	51 SC	6.44
521762230001	AKUYAN 1953	52 03 51.22362	176 12 41.27765	118439.759	985498.644	AK10	-0 10 6.68	0.9999383	42.	5.01
511764140019	AL 11 USN 1943	51 55 47.87892	176 38 44.02269	103679.443	955596.768	AK10	-0 30 52.07	0.9999722	13 SC	4.89
511764140016	AL 29 USN 1943	51 57 16.24793	176 38 47.07347	106411.018	955563.036	AK10	-0 30 54.50	0.9999656	16 SC	5.00
521864130010	AL USN	52 48 44.61251	186 43 33.40049	255500.444	279561.493	AK10	-8 32 51.88	0.9998482		
521861130001	ALAID USE 1943	52 46 19.26650	186 00 7.89354	245298.176	318316.644	AK10	-8 04 38.02	0.9998487	192.0	6.33
521854340005	ALCAN 1947	52 43 25.64731	185 56 4.38281	238096.523	331007.468	AK10	-7 55 1.44	0.9998500	6 SC	6.41
511824410001	ALE 1947	51 52 28.38628	182 47 41.31802	119410.726	532744.597	AK10	-5 24 53.77	0.9999878	3 SC	1.19
521864140010	ALTO	52 54 31.18329	186 41 46.57856	265796.804	283127.534	AK10	-8 31 26.75	0.9998488		
521813320003	ALUGA 1948	52 02 1.09565	181 49 21.75045	131186.095	600866.141	AK10	-4 38 24.89	0.9999456	43.	4.58
521732330001	AM 1941	52 07 1.45134	173 23 4.09342	127555.864	1179107.731	AK10	2 05 3.75	0.9999264	28 SC	4.50
511792120013	AMATIGNAK 1944	51 17 7.47225	179 06 42.89061	36459.715	782916.057	AK10	-2 28 47.83	1.0002097	518.0	- 2.52
511803420008	AMCHITKA LORAN STA PLE 1	51 21 37.89438	180 47 20.85181	51227.426	666614.624	AK10	-3 48 59.62	1.0001757		
511803420010	AMCHITKA LORAN STA PLE 2	51 21 37.16095	180 47 22.72824	51207.470	666576.901	AK10	-3 49 1.12	1.0001758		- 0 06
511803420009	AMCHITKA LORAN STATION 1944	51 21 37.58088	180 47 21.66272	51218.802	666598.322	AK10	-3 49 0.27	1.0001757	2 SC	0 06
511754430002	ANAGAKSIK USN 1934	51 51 13.22644	175 54 3.87656	94996.234	1006815.933	AK10	0 04 43.80	0.9999939	153 SC	3 98
511781120007	AND 1944	51 49 17.21268	178 07 0.54896	93554.471	854063.938	AK10	-1 41 12.99	1.0000036	37 0	3 31

* For conversion of meters to U.S. Survey Feet multiply the meters by 39.37/12.0which is 3.28083333333 to 12 significant figures

* For conversion of meters to International Feet multiply the meters by 100.0/30.48 which is 3.28083989501 to 12 significant figures