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US ARMY WAR COLLEGE

MILITARY STUDIES PROGRAM PAPER

A DATA REDUCTION PACKAGE FOR US ARMY TOPOGRAPHIC COMPUTERS: HAND-HELD PROGRAMMABLE CALCULATORS

BY

MR. WALTER BLACKMER
DEFENSE MAPPING AGENCY

25 MAY 1982

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ABSTRACT

AUTHOR: Mr. Walter Blackmer, Defense Mapping Agency

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CHAPTER I

INTRODUCTION

The US Army and other Department of Defense agencies have in their inventories several types of hand-held, programmable calculators, particularly the Texas Instruments 59 (TI-59). There exists no package of standardized programs for use in the reduction of topographic data. Each using agency has put together a few programs which are of local import.

Discussions were held with personnel of the 171st Engineer Detachment (TOPO) (INTEL) which is part of the US Army Forces Command at Fort McPherson, Georgia and with staff members at the Defense Mapping School (DMS) located at Fort Belvoir, Virginia. These discussions indicate a need for a standardized package of data reduction programs which can be used in the instruction of students of topographic computing and by the operational topographic computer in the field. Most topographic computers are assigned to units engaged in the collection of survey data in support of larger units. They do not have access to immediate data processing equipment to provide the near-real-time data reduction which is required by field units. The use of pre-programmed data reduction which provides consistent and error-free arithmetic calculations on input data can prevent costly delays and mistakes.

The data processing package currently available (Texas Instruments Programmable 59 Calculator with a Surveying Module = $180; Print/Security Cradle, PC 100 Series = $150) is inexpensive enough to be readily available in quantity for all units and, in reality, this equipment could be part of the accountable, but expendable inventory.

CHAPTER II

HISTORICAL VIEW OF TOPOGRAPHICAL ENGINEERS

A complete history of the Topographical Engineers in the US Army would be a very large volume. This study makes no attempt at completeness; it is an essay that tries to capture and communicate some of the atmosphere surrounding the evolution of the Topographical Engineers from their beginnings in the Revolutionary War to its present mission and status. The reader is directed to the many selected references for an extensive and detailed history and an expanding bibliography on the subject.

I was a member of several topographic units located in the United States, Pacific Theater, and Europe during the years 1949 through 1958. These units exhibited the highest degree of professionalism at all times and truly justified a reference to the Corps of Engineers in a letter, dated 5 September 1953, from Major General Julian L. Schley to the Historical Division.

> Insisting on the correct nomenclature, old Colonel E.E. Winslow used to remind young officers that the difference between 'Engineer Corps' and 'Corps of Engineers' was the same as the difference between a 'beer bottle' and a 'bottle of beer'.

The first Topographical Engineer in the history of the United States was Robert Erskine of New Jersey who was appointed Geographer and Surveyor in the Continental Army by General George Washington on 25

July 1777. He was assigned the task of making sketches of the country. He was succeeded upon his death by Simeon De Witt who had been his assistant. Thomas Hutchins was also appointed in the same capacity as a "Geographer of the United States of America." In the postwar years there was little use for topographers and they became land surveyors and geographers. The most significant fact was that these men represented a branch of engineering which was different from that previously known. They were set apart from the usual military engineer. (Geotzmann, 1959).

The first official recognition and appointment of Topographical Engineers for which I found a record happened during the War of 1812 as an act of Congress approved on 3 March 1813. Pertinent regulations prescribed their duties as essentially mappers involved in making plans of military positions, making reconnaissance sketches and notes for intelligence purposes, and exhibiting the positions of contending armies on the fields of battle (Goetzmann 1959 and Beers 1942).

The Topographical Engineers were disbanded in 1815 simply because no provision had been made in the Congressional Act for their retention. Two topographic officers had been retained under other authority and were assigned to complete the surveys on the northern frontier and Lake Champlain. To fulfill the need for frontier military surveys a corps of topographical engineers was established by law under the direction of the Chief of Engineers on 24 April 1816. They operated for more than twenty years until the Army Reorganization Act of 5 July 1838 raised their status to a Corps of Topographical Engineers at last equal to the regular Corps of Engineers and subject only to the control of the Secretary of War (Goetzmann, 1959).

During the period between 1816 and 1838 the Topographical Engineers had been involved in harbor surveys, plans for roads and canals, frontier surveys, and many other types of surveys in all parts of the United States. So numerous were the demands upon their services, that it was impossible to fill all of the requests. Beginning in 1834 the Topographical Engineers were employed in connection with the construction of lighthouses. In 1836 several Topographical Engineers were transferred to Florida for service with the Army against the Seminole Indians (Beers 1942).

The United States Military Academy which was established in 1802 remained as the only school of civil engineering in the United States until the 1830s. An early graduate of West Point, Colonel John James Abert, who was regarded as one of the leading geographers of his time, was the director of the Corps of Topographical Engineers from its inception in 1838 through practically the entire span of its life (1838 to 1863, when it was merged with the Corps of Engineers) (Davis 1967). During that period seventy-two officers served in the corps. Sixty-four of them were graduates of West Point. The topographical officer during the twenty years preceding the Civil War was commonly a polished gentleman and a sophisticated intellectual. This group of men which comprised the Corps of Topographical Engineers was an important part of the exploration of the west. They were required to act as soldier, diplomat, scientist, geographer, geologist, surveyor, mapper, computer, etc. while travelling by foot, horseback, and wagon. They were sent to areas of recognized combat such as during the Mexican War. They helped make this country great and even though the corps was short-lived, their achievements remain as a monument to their dedication and competence (Goetzmann 1966). Some, but not nearly enough, peaks in the Rocky

Mountains bear their names in tribute to their contributions. I have always felt that if the landings on the moon had been accomplished in the Nineteenth Century, the geologist who set foot there would have been a member of the Topographical Engineers.

Many engineers in the US Army rose in rank during the Civil War (Beers 1942). Some statistics are in order to show how significant their contributions were. Of the forty-eight officers in the Corps of Engineers at the beginning of the war, two, Lee and Bureaugard, became full generals, eighteen became major generals, and twelve achieved the rank of brigadier-general. Of the forty-five officers in the Corps of Topographical Engineers, twelve became major generals and six became brigadier generals. The most remembered of these, of course, is Major General George Gordon Meade, who commanded the Army of the Potomac and defeated Lee at Gettysburg.

Not much is written specifically about the topographic engineers after their merger with the Corps of Engineers in 1863, but they must have been put to good use because there were surveys to be done and maps to be made. Many of the surveys had been taken over by the US Coast and Geodetic Survey in the Department of Commerce. There was a company (E) of the Old Battalion of Engineers which was officially designated as a topographical company and served in Cuba during the Spanish American War of 1898 (Davis 1957). West Point continued its tradition of sending only the highest ranking cadets to the Corps of Engineers. A young cadet by the name of Douglas A. MacArthur came to the Corps in 1903.

The Old Battalion passed away in 1901 as Congress authorized three battalions of engineers consisting of four companies each. These engineers performed admirably around the world, notably in the Philippines, but the greatest feat of the era remained to be accomplished by an Army

Engineers colonel, George Washington Goethals, (USMA Class of 1880) who saw to the completion of the Panama Canal where others had failed before.

The topographic engineers surface again as a distinct and sizeable unit on 18 May 1917 in the National Army of the United States as the 29th Engineer Regiment. A unit was so designated at Ft. Devens, Massachusetts on 20 October 1917. The 29th Engineers, Company E, was among the first arrivals in France with General Pershing during World War I. The 29th never functioned as a regiment, but supplied battalions and companies to various armies, corps, and divisions for surveying and map making. One battalion was used for flash and sound ranging for the field artillery. After the war ended the 29th Engineers was disbanded. On 4 July 1923 the 29th Engineer Battalion (Topographic) was activated from the deactivated 17th Engineer Battalion at Fort Humphreys (now Fort Belvoir), Virginia.

Their history was exciting to say the least with assignments to Nicaragua to survey for a possible new canal in 1929, relief work in Managua following the earthquake in 1931, production of topographic maps of New York City from 1931 to 1934, then on to the west coast for the next eight years mapping the Olympic Peninsula and Puget Sound areas of Washington State. Battalion headquarters was stabilized in Portland, Oregon in 1937 where the unit pioneered the development and use of aerial photogrammetric mapping.

War threatened in 1939 causing an immediate expansion of the 29th Engineer Topographic Battalion similar to that in World War I. The greatest wartime task completed by the 29th Engineers was the mapping of the Aleutian chain of islands, including Attu and Kiska. Many topographic units of platoon, company, and battalion size were activated to provide surveying and mapping products during World War II. Most were deactivated immediately following the cessation of hostilities in 1945.

The Post Hostilities Mapping Program was established in October 1945 and assigned to the 29th Engineer Topographic Battalion stationed first at Mandaluyong, Rizal on the outskirts of Manila, Philippine Islands and later at Cavite, Philippine Islands. The battalion had been shipped to the Philippines on 6 July 1945 to support the mapping requirements for the future operations in the Pacific Areas, principally the invasion of Japan. The Post Hostilities Mapping Program was successfully completed six years ahead of schedule in 1954. It was not an easy time for the 29th as twenty-two men lost their lives to headhunters, guerrillas, disease, and accidents during the nine year operation.

Other topographic units which were still active in the 1950s were the 64th BN in Tokyo which deactivated upon arrival of the 29th BN from the Philippine Islands, the 30th BN which eventually moved from the Presidio in California and is still active at Fort Belvoir, Virginia, and the 656th Engrs which supported the Engineer Intelligence Center located in Schwetzingen-Heidelberg, West Germany.

More recent history shows that topographic units were present and fulfilling their basic missions in the Korean and Vietnamese Wars. Technological advances in the art and science of data collection and reduction techniques for geodetic determinations have necessitated the reorganization of units, redefinition of missions, and a shift of responsibilities within the Department of Defense. Since 1972 when the Defense Mapping Agency was established, the Topographical Engineer component of the US Army has shifted its emphasis from map-making to the direct support of combat units.

At present there are 1,886 military topographic troops assigned to the US Army Forces Command. They are members of ten active units, eight reserve units, and one national guard unit. Their locations extend throughout the United States, Panama, and Europe with assignments to I Corps, III Corps, and the XVIII Airborne to mention just a few (See Figure II-1). Their equipment is modern and efficient and training takes place at Ft. Belvoir, Virginia. Presently, their mission is to provide terrain analyses, boundary surveys, establishment of supplemental survey control, and artillery surveys for ranges and firing exercises. As usual, the Topographical Engineers are at the forefront of the military posture of the United States because of their active participation in the Rapid Deployment Joint Task Force (RDJTF).

When it was decreed in 1863 that the Corps of Topographical Engineers would no longer be a separate branch of the US Army and that it was to be merged with the Corps of Engineers, the Military Academy was the main source of instruction for Army topographical officers and schools were established as needed to provide additional topographical training.

Until 1916 topographical officers received training at the School of Application at Willets Point, Long Island, New York. Map reproduction and lithographic schools were established and used during the period from 1916 to 1918 at Fort McNair, Washington, D.C. In 1918 during our involvement in World War I the School of Surveying, Map Reproduction, and Ranging opened at Fort Belvoir (known then as Camp A.A. Humphreys), Virginia to train the much needed officer and enlisted personnel in map making skills.

TOPOGRAPHIC SUPPORT UNITS - 1982

LISTING OF PRESENT TOPOGRAPHIC UNITS

DESIGNATION (See note 1)	MISSION (See note 2)	LOCATION
ACTIVE		
30th Engr BN	A, C, S, T	Ft. Belvoir, VA
63rd Engr CO	C, T	Ft. Bragg, NC
524th Engr CO	C, T	Ft. Hood, TX
531st Engr Det.	T	Ft. Ord, CA
537th Engr Det.	T	Ft. Lewis, WA
542nd Engr Det.	T	Ft. Stewart, GA
573rd Engr Det.	T	Ft. Riley, KS
588th Engr Det.	T	Ft. Carson, CO
714th Engr Det.	T	Ft. Polk, LA
917th Engr Det.	T	Ft. Campbell, KY
RESERVE		
302nd Engr CO	C	Corpus Christi, TX
334th Engr Det.	T	Nashville, TN
343rd Engr CO	S, T	New Kensington, PA
359th Engr Det.	T	San Diego, CA
601st Engr Plt.	MD	Atlanta, GA
624th Engr Plt.	MD	St. Louis, MO
663rd Engr CO	C	Long Beach, CA
759th Engr CO	MD	Annapolis, MD
NATIONAL GUARD		
1203rd Engr BN	A, C, S, T	Dothan, AL

Note 1: BN-Battalion; CO-Company; Det-Detachment; Plt-Platoon.

Note 2: A-Army; C-Cartographic; MD-Map Distribution; S-Survey; T-Terrain Analysis.

Figure II-1

On 1 July 1972 there was formed a new agency within the Department of Defense. This agency was named the Defense Mapping Agency and consisted of five components. One of these components is the Defense Mapping School (formerly the Department of Topography, an academic department of the US Army Engineer School) which is totally committed to producing highly trained and motivated personnel to carry on the long standing traditions initiated many, many years ago by now famous people who served as topographical engineer personnel.

CHAPTER III

A LOOK AT THE COMPUTATIONAL EARTH

General George Washington once said, "Impress on every man from the first to the lowest the importance of the cause and what it is they are contending for." That statement is the basis for including this chapter.

I can find no basic difference between topographic and geodetic computing. There may be some substance to statements about "geodetic" being "attuned to scientific research" and "topographic" being "surface or user oriented." I guess that I would probably agree to differences if I had not started my career as an Army Topographic Computer and since become a professional geodesist. There are also those who would have us believe that because topographic computing is used for survey projects requiring lesser accuracies than those needed in geodetic projects, time and effort will be wasted in upgrading topographic data reduction processes. This may have been true in the days of the "adding machine," but certainly not now with the availability of powerful, hand-held calculators which can be programmed and are capable of performing large iterative-type calculations in a very short time.

I feel that it is very important that anyone who is involved in topographic/geodetic computations have a basic understanding of what they are dealing with. Not only is this a great motivational factor, but those who understand the basic fundamentals of the "mathematical surface" of the earth are capable of making contributions and improvements in the overall computational effort.

The programs which are provided in the appendices to this paper are considered to be geodetic data reductions. One can readily see that they are also applicable to topographic requirements. These programs will provide more accurate results than the standard computations used by the US Army. The reason for this increased accuracy is that the formulas and related forms formerly used were selected for "hand computations" using four function calculators (Friden, Marchant, etc.) or logarithm tables. These types of computations require closed formulas with two or three decimal accuracy in some of the terms. Calculators such as the Texas Instruments Programmable 59 use twelve significant digit accuracy routinely with amazing speed.

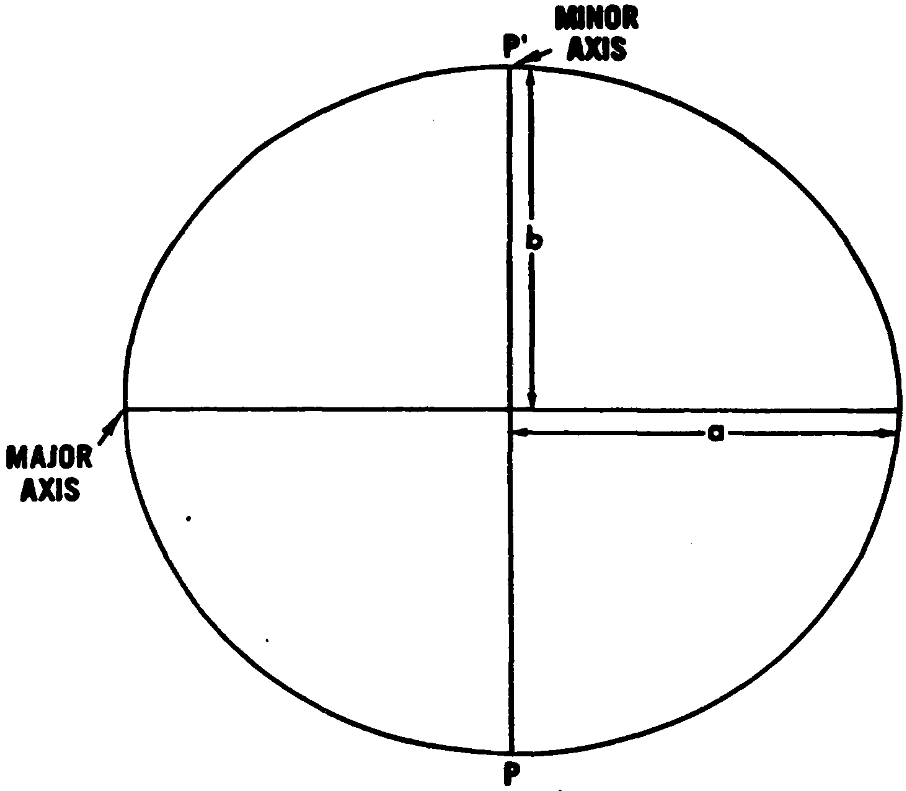
In order to easily perform computations of positions for the surface of the earth (geoid), we must adopt a mathematical surface which closely approximates the actual shape of the earth such as a sphere. The sphere is used in many geodetic problems which can then be solved with sufficient accuracy by well known methods of spherical trigonometry, but the shape of the earth is represented much better by an ellipse because of the flattening at the poles and the equatorial bulge. Figure III-1 (Geodesy for the Layman, 1959) shows the general ellipse used in computations. To achieve a three-dimensional figure: hold the PP' axis and rotate the major axis about it. The resultant ellipsoid in most cases will be very close to a sphere, but because "a" is larger than "b", it takes on somewhat of a short-pumpkin shape.

There are many ellipsoids in use throughout the world. Figure III-2 (Geodesy for the Layman, 1959) lists some examples which may be familiar to some readers. The ultimate goal for the United States is to create and gain acceptance of a world geodetic system which is based on satellite data and will be useful to all. Figure III-3 (Geodesy for the Layman, 1959) shows shape relative to flattening.

Points on the earth can be defined in terms of geodetic coordinates based on ellipsoidal computations. These latitudes, longitudes, and elevations can be transformed to values on other ellipsoids or the actual earth (geoid) when sufficient relativity of the systems is known.

Figure III-4 (Basic Geodesy, 1977) shows the relationship of the three important surfaces that have been discussed.

ELEMENTS OF AN ELLIPSE



a = ONE-HALF OF THE MAJOR AXIS = SEMI-MAJOR AXIS

b = ONE-HALF OF THE MINOR AXIS = SEMI-MINOR AXIS

f = FLATTENING = $\frac{a - b}{a}$

PP' = AXIS OF REVOLUTION OF THE EARTH'S ELLIPSOID

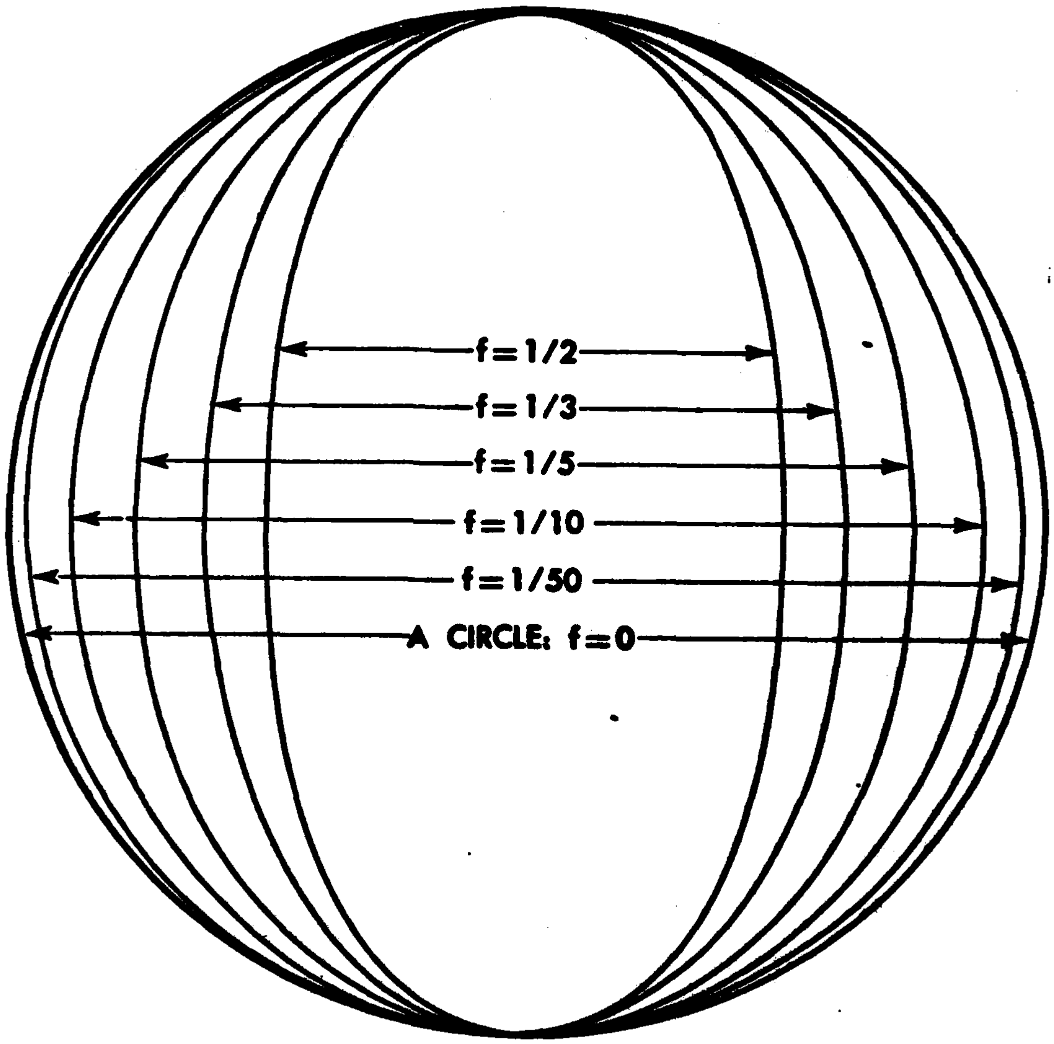
(From Geodesy for the Layman, 1959)
Figure III-1

SOME EXAMPLES OF REFERENCE ELLIPSOIDS

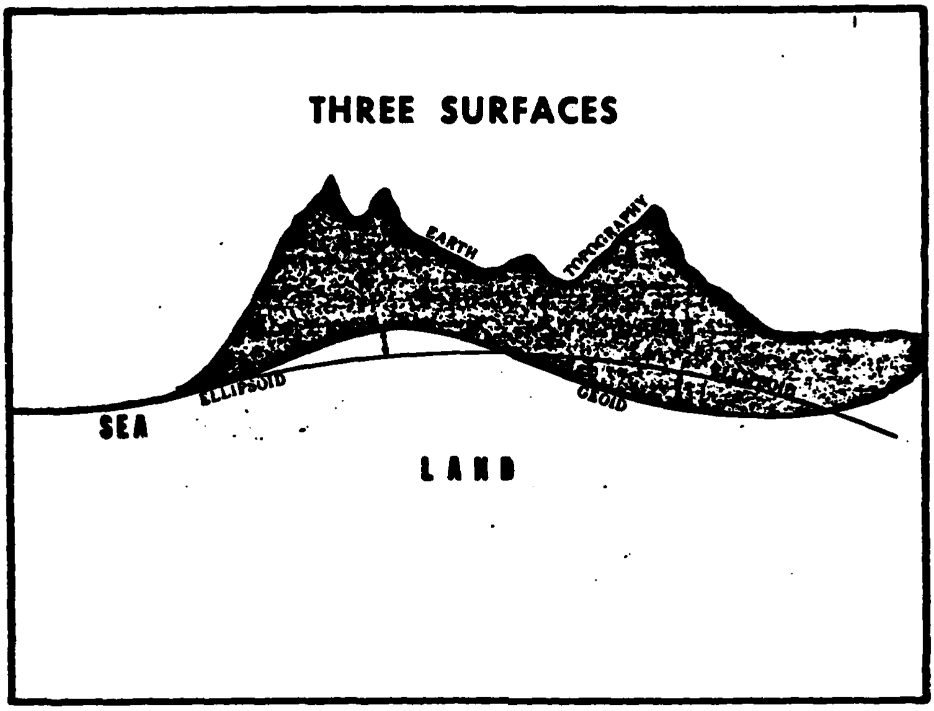
NAME	EQUATORIAL RADIUS	FLATTENING	WHERE USED
Hough (1956)	6,378,270	1/297	New AMS Solution
Krassowsky (1940)	6,378,245	1/298	Russian Datum
International (1924)	6,378,388	1/297	European Datum
Clarke (1866)	6,378,206	1/295	North American Datum
Clarke (1880)	6,378,249	1/293	New French, Africa
Everest (1830)	6,377,276	1/300	Indian Datums
Bessel (1841)	6,377,397	1/299	Tokyo Datum
Helmert (1907)	6,378,200	1/298	Egypt

Figure III-2

THE EARTH'S FLATTENING IS ABOUT 1/300



(From Geodesy for the Layman, 1959)
Figure III-3



Actually, things are quite complicated. When we talk about a pear-shape or an ellipsoid, we obviously do not mean the shape produced by the mountains and valleys, the topography. Since we can measure the elevations of places above sea level (this is what is recorded on topographic maps), we can discount them and inquire into the shape of what is left: that is, the sea-level surface itself, as if it were extended from the sea shore into the land areas without those elevations above it. This sea-level surface is also called the GEOID. The shape of the geoid is what we mean by the Figure of the Earth.

We have found from many measurements that the shape of this geoid is very irregular as compared with an ellipsoid, and we describe these irregularities by the distances from the much smoother ellipsoid. These distances are called GEOIDAL HEIGHTS.

Thus we distinguish three surfaces: the topography, the geoid, and the ellipsoid. Topographic maps give the elevations above sea level (the geoid). Geoidal maps give the geoidal heights in relation to the ellipsoid. Both together give the total height of the topography above the ellipsoid at any point.

(From Basic Geodesy, 1977)
Figure III-4

CHAPTER IV

GENERAL INFORMATION ABOUT THE PROGRAMMABLE CALCULATOR AND ASSOCIATED PRINTER

Today's hand-held calculators are the result of a long line of ingenious methods invented by man to make life's mathematical tasks easier. This is viewed in two ways: The "Type-A" individual sees the latest invention as an aid to his accomplishing more than ever by working extra hours while the "Type-B" perceives all labor-saving devices as a way to get his work done with less effort and to provide him with more leisure time. TO EACH HIS OWN.

We now have hand-held calculators available which have programmability and an optional printing capability. One of these is the Texas Instruments Programmable 59 (hereafter referred to as the "TI-59") with the optional Texas Instruments Print/Security Cradle, PC-100A (hereafter referred to as the "Printer") and is the subject of this discussion.

It is not my intention to provide complete descriptions of the equipment and its capabilities. I do wish to impart some general information and then refer you to the manuals which are provided with each programmable calculator and optional attachments. It is imperative that these manuals be read and studied and that their instructions for the use, care, and maintenance of the equipment are strictly adhered to in every instance. Taking the utmost care with electronic equipment will lead to longer equipment life and fewer maintenance problems along the way.

I presume that each TI-59 calculator purchased by the US Army will include the procurement of the optional Printer. The calculators and printers pairings are interchangeable for operational use which will enhance "direct exchange" procedures in the supply channels. As I noted earlier in this study, initial unit cost is very inexpensive and care must be taken when maintenance versus replacement decisions are made. Repair estimates and minimum repair charges when coupled with handling and shipping costs, soon exceed replacement value. Down-time or the period of time when the unit is below minimum stock levels may make replacement of the item more attractive or necessary.

Texas Instruments Incorporated features pre-programmed modules containing programs which may be of interest to some users. Each calculator is sold with the Master Library module already inserted in the back and a Master Library Manual is also included.

One can now imagine the power of the TI-59 when considering that it can be used as a potent calculator for problems which do not require programs and storage, or with programs stored on magnetic cards, or with pre-recorded programs on modules. No matter how one chooses to employ the calculator there is also the option of using the Printer to provide a hard copy of all calculations for permanent records or for ease in checking the results.

The TI-59 can be operated by a battery pack which is rechargeable. The charger unit also allows the use of 110 Volt AC to power the calculator. When the calculator is attached to the Printer, there is the disadvantage of requiring 110 Volt AC for a power source. I have confidence that this problem will be overcome by Texas Instruments Incorporated because other manufacturers, e.g. Hewlett Packard Incorporated, have already done so.

I consider the Algebraic Operating System (AOS) used by Texas Instruments Incorporated in their calculator to be a distinct advantage to the using community. This is the more common method of entry for calculators used throughout the United States, precludes one more learning aspect for individuals, and is more compatible with the methods used in hand computations.

The calculator is equipped with controls over the Printer. Those input, output, or intermediate values for which hard copy is desired will be printed on command from within the program. The Printer can output both alpha messages and numeric values which can be quite useful in providing "prompts" for operator input or for labelling input, output, or intermediate data.

Note that there are convenient ways to program data reduction solutions in the TI-59 which will provide useful output to the user when the TI-59 is used alone or with the optional printer attached. The use of an output subroutine provides for the insertion or deletion of a critical "HALT" command in a single location to provide visual or hard copy output of data to the user.

This means that when the printer is attached and the "HALT" command is absent, data will be printed and calculations will continue uninterrupted until additional input by the user is required. It also means that when the calculator is detached from the printer and the "HALT" command is present, data will be displayed for recording by the user and calculations will continue only upon the "RUN" command.

All programs can be initialized by depressing the "A" key on the calculator. Exceptions to this rule should be allowed to an experienced operator who does not require some parts of the program such as printed instructions to perform the calculations. Some operators may wish to drop parts of the provided programs, relabel subroutines, provide conditional transfers within the program, or reprogram the calculations to suit their operational purposes. Care must be taken that any modifications do not destroy the validity and/or consistency of the existing program.

Programming can be fun, exciting, and rewarding. I hope that this study effort will act as a stimulus to all potential users which will cause further studies and programming efforts in this area. Each appropriate level headquarters should determine their specific requirements and program needs which could then be modularized by the manufacturer. Cards can be used as the interim solution but should not be depended upon during periods of near-real-time requirements.

For information concerning the Texas Instruments hardware and software the following address and telephone numbers are provided:

Texas Instruments Incorporated
P.O. Box 53
Lubbock, Texas 79408

Toll-free (except Texas): 800-858-1802
(Texas): 800-692-1353

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APPENDIX A

SOLUTION OF GEODETIC TRIANGLES

__Purpose__: Reference TM 5-237, Surveying Computer's Manual, 1964. Page 133, Paragraph 57.

The basic computation in triangulation is the triangle solution. When two angles and one side are known, this case is known as an intersection problem with the third angle concluded from the other two angle observations. Normally, all three angles are observed. The solution of this problem is made by the law of sines (See the "FORMULATION and COMPUTATION" section which follows).

__NOTES__:

1. Given one side and either two or three observed angles of a triangle, this program solves for the amount of spherical excess, triangle misclosure, the two remaining sides (using plane angles), and the three spherical angles for use in the computation of geodetic positions.
2. This program is designed to be used with the TI Printer (PC-100 Series).

__INSTRUCTIONS__:

1. Printer "ON" and, then, Calculator "ON".
2. Load the four sides of the magnetic cards:
   a. CLR, RST, 1, 2nd, OP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

b. 2; Enter Side 2.

c. 3; Enter Side 3.

d. 4; Enter Side 4.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for information and instructions.

FORMULATION and COMPUTATION:

1. Both Cases:

   a. Spherical Excess = (a^2 * sin 2 * sin 3)/(393 E06*sin 1)

   b. The unknown sides are computed using the known side and plane angles through the Law of Sines.

   c. Plane angle equals (Spherical Angle - one-third Spherical Excess).

2. Case of a known side and three observed angles:

   a. Triangle Misclosure = (Sum of the Observed Angles) minus (180 degrees plus Spherical Excess).

   b. Spherical Angle = (Observed Angle) minus (one-third of the Triangle Misclosure).

3. Case of two Observed Angles and their included side (A common condition known as the intersection solution):

   a. Remaining (Concluded) Angle = 180 degrees minus (sum of the two Observed Angles plus the Computed Spherical Excess).

   b. Triangle Misclosure = Zero because this is a "Concluded Triangle."

INPUT DATA:

1. Side opposite angle no. 1, in meters

2. Angle 1.

   a. If observed, enter angle.

b. If not observed, enter zero.

3. Angle 2.

4. Angle 3.

SAMPLE RUNS

```
TRIANGLE COMPS
1 SIDE/ 2 OR 3  ANGS
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS

INPUT DATA IN ORDER:

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0



   32123.456
   90.000231
   60.000115
   30.000057

SPHER EXS:
        1.14    SECS

TRIANGLE CLOSES AT:
        2.89    SECS

COMP SIDE 1 TO 3 IS:
  27819.7139    MTRS

COMP SIDE 1 TO 2 IS:
  16061.6237    MTRS


SPHERICAL ANGLES ARE

   90.000135
   60.000019
   29.595960


THAT WAS AN EASY ONE
WANNA TRY ANOTHER ??

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0
```

```
TRIANGLE COMPS
1 SIDE/ 2 OR 3  ANGS
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS

INPUT DATA IN ORDER:

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0



   32123.456
         0.
   60.000115
   30.000057

SPHER EXS:
        1.14    SECS

TRIANGLE CLOSES AT:
        0.00    SECS

COMP SIDE 1 TO 3 IS:
  27819.7890    MTRS

COMP SIDE 1 TO 2 IS:
  16061.7538    MTRS


SPHERICAL ANGLES ARE

   89.595942
   60.000115
   30.000057


THAT WAS AN EASY ONE
WANNA TRY ANOTHER ??

SIDE/ANG 1-2-3
IF CONCLUDED ANG 1=0
```

PROGRAM LISTING

000	22	INV	100	03	3	050	04	4	150	01	1
001	58	FIX	101	69	OP	051	01	1	151	06	6
002	47	CMS	102	01	01	052	06	6	152	69	OP
003	25	CLR	103	03	3	053	69	OP	153	01	01
004	69	OP	104	07	7	054	01	01	154	04	4
005	00	00	105	00	0	055	01	1	155	00	0
006	03	3	106	00	0	056	07	7	156	03	3
007	07	7	107	01	1	057	06	6	157	00	0
008	03	3	108	03	3	058	03	3	158	03	3
009	05	5	109	03	3	059	00	0	159	06	6
010	02	2	110	06	6	060	00	0	160	06	6
011	04	4	111	00	0	061	00	0	161	03	3
012	01	1	112	00	0	062	03	3	162	02	2
013	03	3	113	69	OP	063	00	0	163	07	7
014	03	3	114	02	02	064	00	0	164	69	OP
015	01	1	115	02	2	065	69	OP	165	02	02
016	69	OP	116	01	1	066	02	02	166	02	2
017	01	01	117	03	3	067	03	3	167	04	4
018	02	2	118	02	2	068	02	2	168	03	3
019	02	2	119	02	2	069	03	3	169	01	1
020	02	2	120	07	7	070	05	5	170	01	1
021	07	7	121	02	2	071	00	0	171	07	7
022	01	1	122	07	7	072	00	0	172	01	1
023	07	7	123	03	3	073	00	0	173	03	3
024	00	0	124	02	2	074	04	4	174	03	3
025	00	0	125	69	OP	075	00	0	175	05	5
026	01	1	126	03	03	076	00	0	176	69	OP
027	05	5	127	04	4	077	69	OP	177	03	03
028	69	OP	128	03	3	078	03	03	178	12	B
029	02	02	129	03	3	079	01	1	179	69	OP
030	03	3	130	06	6	080	03	3	180	05	05
031	02	2	131	06	6	081	03	3	181	98	ADV
032	03	3	132	02	2	082	01	1	182	02	2
033	00	0	133	00	0	083	02	2	183	04	4
034	03	3	134	00	0	084	02	2	184	03	3
035	03	3	135	00	0	085	03	3	185	01	1
036	03	3	136	00	0	086	06	6	186	03	3
037	06	6	137	69	OP	087	69	OP	187	03	3
038	00	0	138	04	04	088	04	04	188	04	4
039	00	0	139	69	OP	089	69	OP	189	01	1
040	69	OP	140	05	05	090	05	05	190	03	3
041	03	03	141	98	ADV	091	02	2	191	07	7
042	69	OP	142	01	1	092	01	1	192	69	OP
043	05	05	143	03	3	093	03	3	193	01	01
044	02	2	144	03	3	094	02	2	194	01	1
045	00	0	145	01	1	095	03	3	195	06	6
046	00	0	146	02	2	096	05	5	196	01	1
047	03	3	147	02	2	097	03	3	197	03	3
048	06	6	148	00	0	098	00	0	198	03	3
049	02	2	149	00	0	099	01	1	199	07	7

200	01	1	250	02	2	300	00	0	350	06	06
201	03	3	251	00	0	301	01	1	351	43	RCL
202	69	OP	252	00	0	302	03	3	352	02	02
203	02	02	253	00	0	303	03	3	353	88	DMS
204	02	2	254	02	2	304	01	1	354	42	STO
205	04	4	255	69	OP	305	69	OP	355	02	02
206	03	3	256	02	02	306	03	03	356	44	SUM
207	01	1	257	02	2	307	02	2	357	06	06
208	00	0	258	00	0	308	02	2	358	38	SIN
209	00	0	259	00	0	309	00	0	359	65	×
210	03	3	260	03	3	310	00	0	360	43	RCL
211	02	2	261	02	2	311	00	0	361	04	04
212	69	OP	262	00	0	312	02	2	362	33	X^2
213	03	03	263	00	0	313	06	6	363	65	×
214	03	3	264	04	4	314	04	4	364	43	RCL
215	05	5	265	00	0	315	00	0	365	03	03
216	01	1	266	00	0	316	01	1	366	38	SIN
217	06	6	267	69	OP	317	69	OP	367	55	÷
218	01	1	268	03	03	318	04	04	368	03	3
219	07	7	269	69	OP	319	69	OP	369	09	9
220	03	3	270	05	05	320	05	05	370	03	3
221	05	5	271	02	2	321	98	ADV	371	52	EE
222	06	6	272	04	4	322	98	ADV	372	06	6
223	02	2	273	02	2	323	98	ADV	373	95	=
224	69	OP	274	01	1	324	91	R/S	374	22	INV
225	04	04	275	00	0	325	99	PRT	375	52	EE
226	69	OP	276	00	0	326	42	STO	376	48	EXC
227	05	05	277	01	1	327	04	04	377	01	01
228	98	ADV	278	05	5	328	25	CLR	378	22	INV
229	76	LBL	279	03	3	329	91	R/S	379	67	EQ
230	89	π	280	02	2	330	99	PRT	380	87	IFF
231	69	OP	281	69	OP	331	42	STO	381	01	1
232	00	00	282	01	01	332	01	01	382	08	8
233	03	3	283	03	3	333	91	R/S	383	00	0
234	06	6	284	01	1	334	99	PRT	384	75	-
235	02	2	285	01	1	335	42	STO	385	43	RCL
236	04	4	286	05	5	336	02	02	386	06	06
237	01	1	287	02	2	337	91	R/S	387	95	=
238	06	6	288	07	7	338	99	PRT	388	98	ADV
239	01	1	289	04	4	339	88	DMS	389	44	SUM
240	07	7	290	01	1	340	42	STO	390	06	06
241	06	6	291	01	1	341	03	03	391	86	STF
242	03	3	292	06	6	342	42	STO	392	01	01
243	69	OP	293	69	OP	343	06	06	393	76	LBL
244	01	01	294	02	02	344	43	RCL	394	87	IFF
245	01	1	295	01	1	345	01	01	395	48	EXC
246	03	3	296	07	7	346	88	DMS	396	01	01
247	03	3	297	01	1	347	42	STO	397	55	÷
248	01	1	298	06	6	348	01	01	398	43	RCL
249	02	2	299	00	0	349	44	SUM	399	01	01

400	38	SIN	450	76	LBL	500	01	1	550	06	6
401	95	=	451	88	DMS	501	07	7	551	06	6
402	42	STO	452	42	STO	502	03	3	552	02	2
403	05	05	453	05	05	503	06	6	553	69	OP
404	98	ADV	454	85	+	504	69	OP	554	04	04
405	69	OP	455	01	1	505	03	03	555	69	OP
406	00	00	456	08	8	506	01	1	556	05	05
407	03	3	457	00	0	507	03	3	557	12	B
408	06	6	458	75	-	508	03	3	558	15	E
409	03	3	459	43	RCL	509	07	7	559	13	C
410	03	3	460	06	06	510	06	6	560	43	RCL
411	02	2	461	95	=	511	02	2	561	03	03
412	03	3	462	94	+/-	512	00	0	562	14	D
413	01	1	463	65	×	513	00	0	563	03	3
414	07	7	464	18	C'	514	69	OP	564	00	0
415	03	3	465	98	ADV	515	04	04	565	00	0
416	05	5	466	42	STO	516	69	OP	566	02	2
417	69	OP	467	07	07	517	05	05	567	04	4
418	01	01	468	22	INV	518	16	A'	568	03	3
419	01	1	469	58	FIX	519	43	RCL	569	06	6
420	07	7	470	03	3	520	07	07	570	06	6
421	04	4	471	07	7	521	58	FIX	571	02	2
422	04	4	472	03	3	522	02	02	572	69	OP
423	03	3	473	05	5	523	69	OP	573	04	04
424	06	6	474	02	2	524	06	06	574	69	OP
425	06	6	475	04	4	525	98	ADV	575	05	05
426	02	2	476	01	1	526	22	INV	576	12	B
427	69	OP	477	03	3	527	58	FIX	577	15	E
428	02	02	478	03	3	528	94	+/-	578	98	ADV
429	69	OP	479	01	1	529	55	÷	579	03	3
430	05	05	480	69	OP	530	18	C'	580	06	6
431	16	A'	481	01	01	531	55	÷	581	03	3
432	43	RCL	482	02	2	532	03	3	582	03	3
433	05	05	483	02	2	533	95	=	583	02	2
434	58	FIX	484	02	2	534	44	SUM	584	03	3
435	02	02	485	07	7	535	01	01	585	01	1
436	69	OP	486	01	1	536	44	SUM	586	07	7
437	06	06	487	07	7	537	02	02	587	03	3
438	22	INV	488	00	0	538	44	SUM	588	05	5
439	58	FIX	489	00	0	539	03	03	589	69	OP
440	55	÷	490	01	1	540	13	C	590	01	01
441	18	C'	491	05	5	541	43	RCL	591	02	2
442	22	INV	492	69	OP	542	02	02	592	04	4
443	87	IFF	493	02	02	543	14	D	593	01	1
444	01	01	494	02	2	544	04	4	594	05	5
445	88	DMS	495	07	7	545	00	0	595	01	1
446	44	SUM	496	03	3	546	00	0	596	03	3
447	01	01	497	02	2	547	02	2	597	02	2
448	44	SUM	498	03	3	548	04	4	598	07	7
449	06	06	499	06	6	549	03	3	599	00	0

600	00	0	650	58	FIX	700	04	04	750	05	05
601	69	OP	651	69	OP	701	69	OP	751	98	ADV
602	02	02	652	00	00	702	05	05	752	22	INV
603	01	1	653	03	3	703	04	4	753	86	STF
604	03	3	654	07	7	704	03	3	754	01	01
605	03	3	655	02	2	705	01	1	755	61	GTO
606	01	1	656	03	3	706	03	3	756	89	π
607	02	2	657	01	1	707	03	3	757	76	LBL
608	02	2	658	03	3	708	01	1	758	11	A
609	02	2	659	03	3	709	03	3	759	98	ADV
610	07	7	660	07	7	710	01	1	760	81	RST
611	01	1	661	00	0	711	01	1	761	76	LBL
612	07	7	662	00	0	712	03	3	762	12	B
613	69	OP	663	69	OP	713	69	OP	763	03	3
614	03	03	664	01	01	714	01	01	764	00	0
615	03	3	665	04	4	715	03	3	765	03	3
616	06	6	666	03	3	716	07	7	766	07	7
617	00	0	667	01	1	717	03	3	767	03	3
618	00	0	668	03	3	718	05	5	768	05	5
619	01	1	669	03	3	719	04	4	769	03	3
620	03	3	670	06	6	720	05	5	770	06	6
621	03	3	671	00	0	721	00	0	771	69	OP
622	05	5	672	00	0	722	00	0	772	04	04
623	01	1	673	01	1	723	69	OP	773	92	RTN
624	07	7	674	03	3	724	02	02	774	76	LBL
625	69	OP	675	69	OP	725	01	1	775	13	C
626	04	04	676	02	02	726	03	3	776	43	RCL
627	69	OP	677	03	3	727	03	3	777	04	04
628	05	05	678	01	1	728	01	1	778	55	÷
629	98	ADV	679	00	0	729	03	3	779	53	(
630	58	FIX	680	00	0	730	02	2	780	43	RCL
631	06	06	681	01	1	731	03	3	781	01	01
632	43	RCL	682	07	7	732	07	7	782	75	-
633	01	01	683	01	1	733	02	2	783	43	RCL
634	22	INV	684	03	3	734	03	3	784	05	05
635	88	DMS	685	03	3	735	69	OP	785	55	÷
636	99	PRT	686	06	6	736	03	03	786	03	3
637	43	RCL	687	69	OP	737	01	1	787	54	)
638	02	02	688	03	03	738	07	7	788	38	SIN
639	22	INV	689	04	4	739	03	3	789	95	=
640	88	DMS	690	05	5	740	05	5	790	65	×
641	99	PRT	691	00	0	741	00	0	791	53	(
642	43	RCL	692	00	0	742	00	0	792	92	RTN
643	03	03	693	03	3	743	07	7	793	76	LBL
644	22	INV	694	02	2	744	01	1	794	14	D
645	88	DMS	695	03	3	745	07	7	795	75	-
646	99	PRT	696	01	1	746	01	1	796	43	RCL
647	98	ADV	697	01	1	747	69	OP	797	05	05
648	98	ADV	698	07	7	748	04	04	798	55	÷
649	22	INV	699	69	OP	749	69	OP	799	03	3

800	54	)
801	38	SIN
802	95	=
803	42	STO
804	07	07
805	01	1
806	05	5
807	03	3
808	02	2
809	03	3
810	00	0
811	03	3
812	03	3
813	00	0
814	00	0
815	69	OP
816	01	01
817	03	3
818	06	6
819	02	2
820	04	4
821	01	1
822	06	6
823	01	1
824	07	7
825	00	0
826	00	0
827	69	OP
828	02	02
829	02	2
830	00	0
831	00	0
832	03	3
833	07	7
834	03	3
835	02	2
836	00	0
837	00	0
838	69	OP
839	03	03
840	92	RTN
841	76	LBL
842	15	E
843	43	RCL
844	07	07
845	58	FIX
846	04	04
847	69	OP
848	06	06
849	98	ADV
850	22	INV
851	58	FIX
852	69	OP
853	00	00
854	92	RTN
855	76	LBL
856	16	A'
857	69	OP
858	00	00
859	03	3
860	06	6
861	01	1
862	07	7
863	01	1
864	05	5
865	03	3
866	06	6
867	69	OP
868	04	04
869	92	RTN
870	76	LBL
871	18	C'
872	03	3
873	06	6
874	00	0
875	00	0
876	95	=
877	92	RTN
878	00	0
879	00	0

APPENDIX B

SOLUTION OF THE GEODETIC PROBLEM

__Purpose__: Reference TM 5-237, Surveying Computer's Manual, 1964 Pp. 175, 181; Paragraphs 67-69, 70-72.

The purpose of this program is to provide solutions to the direct and reverse geodetic problems. It has been structured to provide instructions for the call-up of required instruction sets, input data for use with varied ellipsoids, and for the input of information required for the solution to geodetic problems.

Direct Problem: Given the latitude and longitude of the standpoint and the azimuth and distance from the standpoint to the forepoint, this program computes the latitude and longitude of the forepoint and the azimuth from the forepoint to the standpoint.

Reverse Problem: Given the latitudes and the longitudes of two stations, this program computes the distance and forward and reverse azimuths between the two stations.

__NOTES__:

1. This program has been designed for use with a TI Printer (PC-100 Series).
2. Program constants are metric, therefore, input/output values for distance must be in meters.
3. Angular values are input as one numerical entry with a decimal point

placed between the degrees and minutes values.

4. When inversing stations within 200 meters of each other some degradation of absolute azimuth will occur, but the relative accuracy is maintained. Distances are computed to an accuracy of two millimeters.

INSTRUCTIONS and INPUTS/OUTPUTS:

1. Printer "ON" and, then, Calculator "ON".
2. Load the four sides of the magnetic cards:
   a. CLR, RST, 1, 2nd OP 17, INV, 2nd, WRITE; Enter Side 1.
   b. 2, INV, 2nd, WRITE; Enter Side 2.
   c. 3, INV, 2nd, WRITE; Enter Side 3.
   d. 4, INV, 2nd, WRITE; Enter Side 4.

If a blinking number appears after a side has been fed through the calculator, repeat the action, starting at CLR, for that side. Refer to operating instructions maual if difficulty occurs.

3. Depress "A" for information and instructions:
   a. Title of program and constants.
   b. Depress "E" to input new constants or go to next instruction (See also paragraph 4).
   c. Depress "B" to use the program for a direct solution or depress "C" to use the program for reverse solution.
   d. After any solution has been computed, it is not necessary to depress the user label to repeat the same type solution. If new constants are to be entered or another type solution is desired, it is necessary to depress the applicable user label.

4. The following constants are associated with the listed ellipsoids:

Ellipsoid	1/E*	C **
International	147.750	6 399 936.606
Bessel	148.827	6 398 786.846
Everest	149.651	6 398 547.992
Clarke 1880	145.983	6 400 057.735
Australian Nat.	148.357	6 399 617.223
Mercury 1960	148.400	6 399 619.635
Fischer, SE Asia	148.400	6 399 608.600
Hough 1960	147.750	6 399 818.210
Airy	148.913	6 398 941.304
Krassovsky	148.400	6 399 698.900
NWL 9 D	148.380	6 399 602.200

* $1/E - (1-f)^2 / (2f-f^2)$

* * $C = a/(1-f)$

Where: a = equatorial radius

f = reciprocal of the flattening

5. The sign convention for input/output geodetic coordinates are as follows:

	Positive	Negative
Latitude :	North	South
Longitude :	West	East

6. For longitudinal values in excess of one-hundred degrees, subtract one-hundred degrees from the absolute degrees value before input and add one-hundred degrees to the absolute degrees value after output.

Example: Input 125° as 25°
Add 100° back to output longitude

Input -125° as -25°
Subtract 100° from output longitude

INPUT DATA:

1. Direct Problem (Position Computation)

   a. Latitude (1): N (+), S(-).

   b. Longitude (1): W(+), E(-).

   c. Azimuth (Clockwise from 0° North).

   d. Distance, Station 1 to Station 2, in meters.

2. Reverse Problem (Inverse Position Computation)

   a. Latitude (1): N(+), S(-).

   b. Longitude (1): W(+), E(-).

   c. Latitude (2): N(+), S(-).

   d. Longitude (2): W(+), E(-).

3. New Constants (See listing of ellipsoids).

   a. "C".

   b. "1/E".

FORMULATION and COMPUTATION:

1. Change steps 20 - 26 and 45 - 50 for use with other ellipsoids.

2. <u>Angles are in radians in the following formulas:</u>

$$\theta = s/c \qquad \phi_m = \phi_1 + \tfrac{1}{2}\theta \cos\alpha_{12}$$

$$V_m^2 = 1 + \varepsilon\cos^2\phi_m \qquad e = \tfrac{1}{2}\theta^2 V_m^4 \sin\alpha_{12}\cos\alpha_{12}$$

$$\phi_2' = 2\phi_m - \phi_1 \qquad \eta = e\tan\alpha_{12}\tan\phi_2'$$

$$\phi_2 = \phi_1 + \theta V_m^3 \cos(\alpha_{12} - \tfrac{2}{3}e) - \eta$$

$$\lambda_2 = \lambda_1 - \theta V_2 \sin(\alpha_{12} - \tfrac{1}{3}e)(\sec(\phi_2 + \tfrac{1}{3}\eta))$$

$$\text{where } V_2 = (1 + \varepsilon\cos^2\phi_2)^{1/2}$$

$$\alpha_{21} = \alpha_{12} \pm \pi \pm (\Delta\lambda \sin\phi_m) \qquad \text{North} = 0^\circ \text{ Az.}$$

η is the angular distance along the meridian of P_1 from ϕ_2 to the foot of the perpendicular from P_2.

This formula uses the azimuth of the normal section, not the azimuth of the geodesic. The difference between the two is negligible (<0.028 at 100 KM)

INVERSE SOLUTION

Source of Equations: H. F. Rainsford's formula as given in Empire Survey Review 71, 1949. Terms beyond third order have been omitted and fourth order elliptic terms have been omitted from third order terms. Expansions are used in terms of $\xi = \Delta\phi$ and $\eta = \Delta\lambda \cos\phi$. All angles are in radians. Longitude is positive east.

c = polar radius

ε = the square of second eccentricity

$\phi = (1/2)(\phi_1 + \phi_2)$

$\xi = (\phi_2 - \phi_1)$

$\eta = (\lambda_2 - \lambda_1)\cos\phi$

$t = \tan \phi$

$D = \varepsilon \cos^2\phi$

$V^2 = 1 + D$

$A_1 = (1/8)\, D\, (1 - t^2)$

$B_1 = -(1/24)(2 + 3t^2 + 2D)$

$A_2 = (1/24)(1 - D(1 + 9t^2))$

$B_2 = -(1/24)t^2$

$A_3 = (1/24)(3 + 2D)$

$B_3 = (1/12)(1 + D)$

$x = (\xi/V^3)(1 + A_1\xi^2 + B_1\eta^2)$

$y = (\eta/V)(1 + A_2\xi^2 + B_2\eta^2)$

$z = t\eta(1 + A_3\xi^2 + B_3\eta^2)$

$S = c\sqrt{x^2 + y^2} = cr$

$\tan A = y/x$ or $\cot A = x/y$

$\alpha_{12} = A - (1/2)z$

$\alpha_{21} = A + (1/2)z \pm \pi$

These equations give an accuracy of about 1:10⁶ up to 200 km or more in low and medium latitudes, up to 160 km at latitude 60°, and progressively less in higher latitudes.

SAMPLE RUNS

```
POSITION AND INVERSE
   6399902.6        =C
      146.74      =1/E

E: FOR NEW CONSTANTS
B: DIRECT/C: INVERSE
```

```
INPUT            C:1/E

   63998999.5
        148.23
B: DIRECT/C: INVERSE
```

```
DIRCT COMP      INPUT
LAT1/LON1:AZ/N:DIS/M

 30.12131234
 75.10154321
  60.2609155
    11061.08

         30.
         15.
    10.22220

         75.
          4.
    15.55550

        240.
         29.
      10.333
```

```
INVRS COMP      INPUT
LAT1/LON1: LAT2/LON2

 30.12131234
 75.10154321

 30.15102222
 75.04155555

         60.
         26.
       9.157

        240.
         29.
      10.335

  11061.0796
```

PROGRAM LISTING

000	98	ADV	050	05	05	100	69	OP	150	04	4
001	03	3	051	06	6	101	01	01	151	69	OP
002	03	3	052	04	4	102	03	3	152	01	01
003	03	3	053	01	1	103	05	5	153	03	3
004	02	2	054	05	5	104	00	0	154	05	5
005	03	3	055	69	OP	105	00	0	155	01	1
006	06	6	056	04	04	106	03	3	156	07	7
007	02	2	057	06	6	107	01	1	157	01	1
008	04	4	058	03	3	108	01	1	158	05	5
009	03	3	059	09	9	109	07	7	159	03	3
010	07	7	060	09	9	110	04	4	160	07	7
011	69	OP	061	09	9	111	03	3	161	06	6
012	01	01	062	00	0	112	69	OP	162	03	3
013	02	2	063	02	2	113	02	02	163	69	OP
014	04	4	064	93	.	114	01	1	164	02	02
015	03	3	065	06	6	115	05	5	165	01	1
016	02	2	066	42	STO	116	03	3	166	05	5
017	03	3	067	09	09	117	02	2	167	06	6
018	01	1	068	69	OP	118	03	3	168	02	2
019	00	0	069	06	06	119	01	1	169	00	0
020	00	0	070	06	6	120	03	3	170	00	0
021	01	1	071	04	4	121	06	6	171	02	2
022	03	3	072	00	0	122	69	OP	172	04	4
023	69	OP	073	02	2	123	03	03	173	03	3
024	02	02	074	06	6	124	03	3	174	01	1
025	03	3	075	03	3	125	07	7	175	69	OP
026	01	1	076	01	1	126	01	1	176	03	03
027	01	1	077	07	7	127	03	3	177	04	4
028	06	6	078	69	OP	128	03	3	178	02	2
029	00	0	079	04	04	129	01	1	179	01	1
030	00	0	080	01	1	130	03	3	180	07	7
031	02	2	081	04	4	131	07	7	181	03	3
032	04	4	082	06	6	132	03	3	182	05	5
033	03	3	083	93	.	133	06	6	183	03	3
034	01	1	084	07	7	134	69	OP	184	06	6
035	69	OP	085	04	4	135	04	04	185	01	1
036	03	03	086	42	STO	136	98	ADV	186	07	7
037	04	4	087	08	08	137	69	OP	187	69	OP
038	02	2	088	69	OP	138	05	05	188	04	04
039	01	1	089	06	06	139	76	LBL	189	69	OP
040	07	7	090	01	1	140	88	DMS	190	05	05
041	03	3	091	07	7	141	01	1	191	98	ADV
042	05	5	092	06	6	142	04	4	192	98	ADV
043	03	3	093	02	2	143	06	6	193	98	ADV
044	06	6	094	00	0	144	02	2	194	25	CLR
045	01	1	095	00	0	145	00	0	195	91	R/S
046	07	7	096	02	2	146	00	0	196	76	LBL
047	69	OP	097	01	1	147	01	1	197	30	TAN
048	04	04	098	03	3	148	06	6	198	87	IFF
049	69	OP	099	02	2	149	02	2	199	01	01

200	38	SIN
201	76	LBL
202	39	COS
203	14	D
204	02	2
205	04	4
206	03	3
207	01	1
208	04	4
209	02	2
210	03	3
211	05	5
212	03	3
213	06	6
214	69	OP
215	01	01
216	19	D'
217	02	2
218	07	7
219	01	1
220	03	3
221	03	3
222	07	7
223	00	0
224	03	3
225	69	OP
226	03	03
227	06	6
228	03	3
229	02	2
230	07	7
231	03	3
232	02	2
233	03	3
234	01	1
235	00	0
236	03	3
237	69	OP
238	04	04
239	69	OP
240	05	05
241	76	LBL
242	33	X^2
243	98	ADV
244	98	ADV
245	98	ADV
246	25	CLR
247	91	R/S
248	99	PRT
249	42	STO
250	01	01
251	91	R/S
252	99	PRT
253	42	STO
254	03	03
255	98	ADV
256	91	R/S
257	99	PRT
258	42	STO
259	02	02
260	91	R/S
261	99	PRT
262	94	+/-
263	10	E'
264	48	EXC
265	03	03
266	10	E'
267	44	SUM
268	03	03
269	16	A'
270	10	E'
271	42	STO
272	01	01
273	48	EXC
274	02	02
275	10	E'
276	22	INV
277	44	SUM
278	02	02
279	85	+
280	16	A'
281	95	=
282	55	÷
283	02	2
284	95	=
285	30	TAN
286	42	STO
287	01	01
288	22	INV
289	30	TAN
290	39	COS
291	49	PRD
292	03	03
293	33	X^2
294	55	÷
295	43	RCL
296	08	08
297	85	+
298	01	1
299	95	=
300	34	√X
301	42	STO
302	04	04
303	02	2
304	00	0
305	42	STO
306	05	05
307	85	+
308	03	3
309	65	×
310	43	RCL
311	02	02
312	33	X^2
313	85	+
314	02	2
315	65	×
316	17	B'
317	33	X^2
318	95	=
319	55	÷
320	02	2
321	65	×
322	16	A'
323	65	×
324	17	B'
325	55	÷
326	43	RCL
327	05	05
328	95	=
329	42	STO
330	07	07
331	43	RCL
332	02	02
333	33	X^2
334	75	-
335	16	A'
336	33	X^2
337	65	×
338	17	B'
339	33	X^2
340	85	+
341	43	RCL
342	05	05
343	95	=
344	55	÷
345	43	RCL
346	04	04
347	65	×
348	17	B'
349	55	÷
350	43	RCL
351	05	05
352	95	=
353	42	STO
354	00	00
355	32	X:T
356	43	RCL
357	00	00
358	33	X^2
359	42	STO
360	06	06
361	02	2
362	85	+
363	03	3
364	65	×
365	16	A'
366	33	X^2
367	95	=
368	65	×
369	17	B'
370	33	X^2
371	75	-
372	43	RCL
373	05	05
374	95	=
375	65	×
376	43	RCL
377	02	02
378	55	÷
379	43	RCL
380	04	04
381	45	Y^x
382	03	3
383	55	÷
384	43	RCL
385	05	05
386	95	=
387	42	STO
388	03	03
389	22	INV
390	37	P/R
391	94	+/-
392	85	+
393	89	π
394	55	÷
395	02	2
396	95	=
397	42	STO
398	02	02
399	75	-

400	43	RCL	450	05	5	500	91	R/S	550	17	B'
401	07	07	451	03	3	501	99	PRT	551	38	SIN
402	95	=	452	07	7	502	55	÷	552	65	×
403	86	STF	453	69	OP	503	43	RCL	553	17	B'
404	02	02	454	01	01	504	09	09	554	39	COS
405	18	C'	455	19	D'	505	95	=	555	95	=
406	25	CLR	456	01	1	506	42	STO	556	42	STO
407	32	X:T	457	03	3	507	04	04	557	06	06
408	43	RCL	458	04	4	508	16	A'	558	65	×
409	02	02	459	06	6	509	10	E'	559	17	B'
410	75	-	460	06	6	510	42	STO	560	30	TAN
411	89	π	461	03	3	511	01	01	561	65	×
412	85	+	462	03	3	512	43	RCL	562	53	(
413	43	RCL	463	01	1	513	02	02	563	02	2
414	07	07	464	06	6	514	10	E'	564	65	×
415	95	=	465	02	2	515	42	STO	565	43	RCL
416	86	STF	466	69	OP	516	02	02	566	00	00
417	02	02	467	03	03	517	17	B'	567	75	-
418	18	C'	468	01	1	518	10	E'	568	16	A'
419	17	B'	469	06	6	519	42	STO	569	54	)
420	33	X^2	470	02	2	520	03	03	570	30	TAN
421	85	+	471	04	4	521	39	COS	571	95	=
422	43	RCL	472	03	3	522	65	×	572	42	STO
423	06	06	473	06	6	523	43	RCL	573	07	07
424	95	=	474	06	6	524	04	04	574	94	+/-
425	34	√X	475	03	3	525	55	÷	575	55	÷
426	65	×	476	03	3	526	02	2	576	02	2
427	43	RCL	477	00	0	527	85	+	577	85	+
428	09	09	478	69	OP	528	16	A'	578	16	A'
429	95	=	479	04	04	529	95	=	579	85	+
430	58	FIX	480	69	OP	530	42	STO	580	53	(
431	04	04	481	05	05	531	00	00	581	43	RCL
432	98	ADV	482	76	LBL	532	39	COS	582	05	05
433	99	PRT	483	34	√X	533	33	X^2	583	45	Y^X
434	22	INV	484	98	ADV	534	55	÷	584	03	3
435	58	FIX	485	98	ADV	535	43	RCL	585	65	×
436	22	INV	486	98	ADV	536	08	08	586	43	RCL
437	87	IFF	487	25	CLR	537	85	+	587	04	04
438	01	01	488	91	R/S	538	01	1	588	65	×
439	33	X^2	489	99	PRT	539	95	=	589	53	(
440	76	LBL	490	42	STO	540	34	√X	590	17	B'
441	38	SIN	491	01	01	541	42	STO	591	75	-
442	14	D	492	91	R/S	542	05	05	592	43	RCL
443	01	1	493	99	PRT	543	33	X^2	593	06	06
444	06	6	494	42	STO	544	33	X^2	594	55	÷
445	02	2	495	02	02	545	65	×	595	03	3
446	04	4	496	91	R/S	546	43	RCL	596	54	)
447	03	3	497	99	PRT	547	04	04	597	39	COS
448	05	5	498	42	STO	548	33	X^2	598	95	=
449	01	1	499	03	03	549	65	×	599	42	STO

600	01	01	650	04	04	700	76	LBL	750	59	INT
601	18	C'	651	85	+	701	10	E'	751	99	PRT
602	43	RCL	652	17	B'	702	88	DMS	752	94	+/-
603	01	01	653	75	-	703	65	×	753	85	+
604	39	COS	654	03	3	704	89	π	754	43	RCL
605	33	X²	655	65	×	705	55	÷	755	05	05
606	55	÷	656	89	π	706	01	1	756	65	×
607	43	RCL	657	95	=	707	08	8	757	01	1
608	08	08	658	86	STF	708	00	0	758	00	0
609	85	+	659	02	02	709	95	=	759	00	0
610	01	1	660	18	C'	710	92	RTN	760	95	=
611	95	=	661	87	IFF	711	76	LBL	761	65	×
612	34	ΓX	662	01	01	712	18	C'	762	01	1
613	65	×	663	34	ΓX	713	98	ADV	763	00	0
614	43	RCL	664	76	LBL	714	76	LBL	764	00	0
615	04	04	665	11	A	715	44	SUM	765	95	=
616	65	×	666	47	CMS	716	77	GE	766	87	IFF
617	53	(	667	70	RAD	717	35	1/X	767	02	02
618	17	B'	668	14	D	718	85	+	768	70	RAD
619	75	-	669	81	RST	719	02	2	769	58	FIX
620	43	RCL	670	76	LBL	720	65	×	770	05	05
621	06	06	671	12	B	721	89	π	771	61	GTO
622	55	÷	672	86	STF	722	95	=	772	22	INV
623	06	6	673	01	01	723	61	GTO	773	76	LBL
624	54	)	674	61	GTO	724	44	SUM	774	70	RAD
625	38	SIN	675	30	TAN	725	76	LBL	775	58	FIX
626	55	÷	676	76	LBL	726	35	1/X	776	03	03
627	53	(	677	13	C	727	65	×	777	76	LBL
628	16	A'	678	22	INV	728	01	1	778	22	INV
629	85	+	679	86	STF	729	08	8	779	99	PRT
630	43	RCL	680	01	01	730	00	0	780	22	INV
631	07	07	681	61	GTO	731	55	÷	781	58	FIX
632	55	÷	682	30	TAN	732	89	π	782	22	INV
633	06	6	683	76	LBL	733	95	=	783	86	STF
634	54	)	684	14	D	734	22	INV	784	02	02
635	39	COS	685	22	INV	735	88	DMS	785	92	RTN
636	95	=	686	58	FIX	736	42	STO	786	76	LBL
637	42	STO	687	69	OP	737	05	05	787	19	D'
638	04	04	688	00	00	738	59	INT	788	01	1
639	94	+/-	689	92	RTN	739	99	PRT	789	05	5
640	85	+	690	76	LBL	740	22	INV	790	03	3
641	43	RCL	691	16	A'	741	44	SUM	791	02	2
642	02	02	692	43	RCL	742	05	05	792	03	3
643	95	=	693	01	01	743	43	RCL	793	00	0
644	18	C'	694	92	RTN	744	05	05	794	03	3
645	43	RCL	695	76	LBL	745	65	×	795	03	3
646	00	00	696	17	B'	746	01	1	796	69	OP
647	38	SIN	697	43	RCL	747	00	0	797	02	02
648	65	×	698	03	03	748	00	0	798	02	2
649	43	RCL	699	92	RTN	749	95	=	799	04	4

800	03	3
801	01	1
802	03	3
803	03	3
804	04	4
805	01	1
806	03	3
807	07	7
808	69	OP
809	04	04
810	69	OP
811	05	05
812	02	2
813	07	7
814	01	1
815	03	3
816	03	3
817	07	7
818	00	0
819	02	2
820	06	6
821	03	3
822	69	OP
823	01	01
824	02	2
825	07	7
826	03	3
827	02	2
828	03	3
829	01	1
830	00	0
831	02	2
832	06	6
833	02	2
834	69	OP
835	02	02
836	92	RTN
837	76	LBL
838	15	E
839	14	D
840	02	2
841	04	4
842	03	3
843	01	1
844	03	3
845	03	3
846	04	4
847	01	1
848	03	3
849	07	7

850	69	OP
851	01	01
852	01	1
853	05	5
854	06	6
855	02	2
856	00	0
857	02	2
858	06	6
859	03	3
860	01	1
861	07	7
862	69	OP
863	04	04
864	69	OP
865	05	05
866	98	ADV
867	98	ADV
868	98	ADV
869	25	CLR
870	91	R/S
871	99	PRT
872	42	STO
873	09	09
874	91	R/S
875	99	PRT
876	42	STO
877	08	08
878	61	GTO
879	88	DMS

APPENDIX C

REDUCTION TO CENTER

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 133 Paragraph 56 a

The computation of the eccentric reduction provides the correction which, when properly applied to the observed direction, reduces it to the value it would have been had the instrument or target or both not been eccentric.

NOTES:

1. This program is designed to be used with the TI Printer (PC-100 Series). Simple modification of the program will provide stop/output for a TI 59 calculator without a printer attachment.
2. The values of the known lengths may be entered in any consistent linear system.
3. The angular value at the occupied station from the near station to the distant station is input as one numerical value with a decimal point placed between the degrees and minutes values.

INSTRUCTIONS:

1. Printer "ON", and, then, Calculator "ON".
2. Load the two sides of the magnetic card.
   a. CLR, RST, 1, 2nd, OP 17, 1, INV, 2nd, WRITE; Enter Side 1.
   b. 2; Enter Side 2.

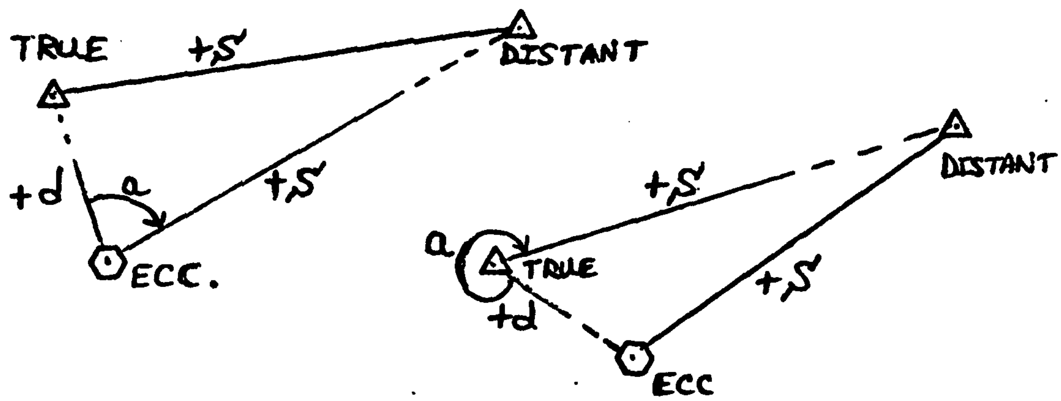
Note: The underlined numbers may be replaced by zeroes. Refer to the operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and input instruction.
4. For explanation of "cases", depress "B", then after the information is provided, depress "A" for input and computations.
5. Computed/output values will be followed by a print of the station number and "d". If either a new station or a new "d" is to be used, depress "A" and input a complete set of data.

INPUT DATA:

1. Station ID number.
2. "d": Distance between True and Eccentric stations, in meters.
3. Case number.
4. Distance, in meters, from the True or Eccentric station to the far station (according to case number).
5. Clockwise angle at the occupied station from the near station to the far station.

FORMULATION and COMPUTATION:



Note: In like figures the eccentric and swing angles are numerically equal, but opposite in sign.

$$\text{Angle (Seconds)} = \sin^{-1}\left(\frac{d \sin a}{S}\right)$$

When two sides and the included angle comprise the input data, the law of cosines is utilized to compute the side opposite the observed station and, then, that value is used in the law of sines (above).

SAMPLE RUNS

```
CASE: LENGTH TO :STA
 NO. :  FAR   STA :OCC

    1  TRU         TRU
    2        ECC   TRU
    3  TRU         ECC
    4        ECC   ECC


1,3 SWG/2,4 RED  ANG


INPUT  FOR  ECC  RED
STA/D//CASE/DIST/ANG



        101.

        1.54



          1.

    13000.276
        280.

      -24.06     SECS



        101.

        1.54



          2.

    13000.276
    99.593594

       24.06     SECS
```

```
        101.

        1.54



          3.

      13000.
        280.

      -24.06     SECS



        101.

        1.54



          4.

      13000.
    99.593594

       24.06     SECS



        101.

        1.54
```

000	25	CLR
001	22	INV
002	58	FIX
003	98	ADV
004	98	ADV
005	98	ADV
006	91	R/S
007	42	STD
008	07	07
009	99	PRT
010	91	R/S
011	42	STD
012	01	01
013	76	LBL
014	38	SIN
015	43	RCL
016	01	01
017	98	ADV
018	99	PRT
019	98	ADV
020	98	ADV
021	98	ADV
022	91	R/S
023	42	STD
024	06	06
025	99	PRT
026	98	ADV
027	91	R/S
028	42	STD
029	03	03
030	42	STD
031	05	05
032	99	PRT
033	91	R/S
034	99	PRT
035	88	DMS
036	42	STD
037	04	04
038	43	RCL
039	06	06
040	75	-
041	02	2
042	95	=
043	67	EQ
044	34	ΓX
045	43	RCL
046	06	06
047	75	-
048	03	3
049	95	=
050	67	EQ
051	34	ΓX
052	43	RCL
053	01	01
054	33	X²
055	85	+
056	43	RCL
057	03	03
058	33	X²
059	75	-
060	43	RCL
061	01	01
062	65	×
063	43	RCL
064	03	03
065	65	×
066	43	RCL
067	04	04
068	39	COS
069	65	×
070	02	2
071	95	=
072	34	ΓX
073	42	STD
074	05	05
075	76	LBL
076	34	ΓX
077	43	RCL
078	01	01
079	65	×
080	43	RCL
081	04	04
082	38	SIN
083	55	÷
084	43	RCL
085	05	05
086	95	=
087	22	INV
088	38	SIN
089	65	×
090	03	3
091	06	6
092	00	0
093	00	0
094	95	=
095	42	STD
096	08	08
097	03	3
098	06	6
099	01	1
100	07	7
101	01	1
102	05	5
103	03	3
104	06	6
105	69	OP
106	04	04
107	43	RCL
108	08	08
109	98	ADV
110	58	FIX
111	02	02
112	69	OP
113	06	06
114	22	INV
115	58	FIX
116	43	RCL
117	07	07
118	98	ADV
119	98	ADV
120	98	ADV
121	99	PRT
122	61	GTO
123	38	SIN
124	76	LBL
125	11	A
126	22	INV
127	58	FIX
128	69	OP
129	00	00
130	02	2
131	04	4
132	03	3
133	01	1
134	03	3
135	03	3
136	04	4
137	01	1
138	03	3
139	07	7
140	69	OP
141	01	01
142	02	2
143	01	1
144	03	3
145	02	2
146	03	3
147	05	5
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149	02	02
150	01	1
151	07	7
152	01	1
153	05	5
154	01	1
155	05	5
156	69	OP
157	03	03
158	03	3
159	05	5
160	01	1
161	07	7
162	01	1
163	06	6
164	69	OP
165	04	04
166	69	OP
167	05	05
168	03	3
169	06	6
170	03	3
171	07	7
172	01	1
173	03	3
174	06	6
175	03	3
176	01	1
177	06	6
178	69	OP
179	01	01
180	06	6
181	03	3
182	06	6
183	03	3
184	01	1
185	05	5
186	01	1
187	03	3
188	03	3
189	06	6
190	69	OP
191	02	02
192	01	1
193	07	7
194	06	6
195	03	3
196	01	1
197	06	6
198	02	2
199	04	4

200	03	3
201	06	6
202	69	OP
203	03	03
204	03	3
205	07	7
206	06	6
207	03	3
208	01	1
209	03	3
210	03	3
211	01	1
212	02	2
213	02	2
214	69	OP
215	04	04
216	69	OP
217	05	05
218	47	CMS
219	81	RST
220	00	0
221	00	0
222	00	0
223	00	0
224	00	0
225	00	0
226	00	0
227	00	0
228	00	0
229	00	0
230	00	0
231	00	0
232	00	0
233	00	0
234	00	0
235	00	0
236	00	0
237	00	0
238	00	0
239	00	0
240	01	1
241	05	5
242	01	1
243	03	3
244	03	3
245	06	6
246	01	1
247	07	7
248	06	6
249	02	2
250	69	OP
251	01	01
252	02	2
253	07	7
254	01	1
255	07	7
256	03	3
257	01	1
258	02	2
259	02	2
260	69	OP
261	02	02
262	03	3
263	07	7
264	02	2
265	03	3
266	00	0
267	00	0
268	03	3
269	07	7
270	03	3
271	02	2
272	69	OP
273	03	03
274	06	6
275	02	2
276	03	3
277	06	6
278	03	3
279	07	7
280	01	1
281	03	3
282	69	OP
283	04	04
284	69	OP
285	05	05
286	03	3
287	01	1
288	03	3
289	02	2
290	04	4
291	00	0
292	06	6
293	02	2
294	69	OP
295	01	01
296	02	2
297	01	1
298	01	1
299	03	3
300	03	3
301	05	5
302	69	OP
303	02	02
304	03	3
305	06	6
306	03	3
307	07	7
308	01	1
309	03	3
310	69	OP
311	03	03
312	06	6
313	02	2
314	03	3
315	02	2
316	01	1
317	05	5
318	01	1
319	05	5
320	69	OP
321	04	04
322	69	OP
323	05	05
324	98	ADV
325	69	OP
326	00	00
327	00	0
328	02	2
329	69	OP
330	01	01
331	03	3
332	07	7
333	03	3
334	05	5
335	04	4
336	01	1
337	69	OP
338	02	02
339	03	3
340	07	7
341	03	3
342	05	5
343	04	4
344	01	1
345	69	OP
346	04	04
347	69	OP
348	05	05
349	69	OP
350	00	00
351	00	0
352	03	3
353	69	OP
354	01	01
355	01	1
356	07	7
357	01	1
358	05	5
359	01	1
360	05	5
361	69	OP
362	03	03
363	03	3
364	07	7
365	03	3
366	05	5
367	04	4
368	01	1
369	69	OP
370	04	04
371	69	OP
372	05	05
373	69	OP
374	00	00
375	00	0
376	04	4
377	69	OP
378	01	01
379	03	3
380	07	7
381	03	3
382	05	5
383	04	4
384	01	1
385	69	OP
386	02	02
387	01	1
388	07	7
389	01	1
390	05	5
391	01	1
392	05	5
393	69	OP
394	04	04
395	69	OP
396	05	05
397	69	OP
398	00	00
399	00	0

400	05	5
401	69	OP
402	01	01
403	01	1
404	07	7
405	01	1
406	05	5
407	01	1
408	05	5
409	69	OP
410	03	03
411	01	1
412	07	7
413	01	1
414	05	5
415	01	1
416	05	5
417	69	OP
418	04	04
419	69	OP
420	05	05
421	98	ADV
422	98	ADV
423	00	0
424	02	2
425	05	5
426	07	7
427	00	0
428	04	4
429	00	0
430	00	0
431	03	3
432	06	6
433	69	OP
434	01	01
435	04	4
436	03	3
437	02	2
438	02	2
439	06	6
440	03	3
441	00	0
442	03	3
444	07	7
445	69	OP
446	02	02
447	00	0
448	05	5
449	00	0
450	00	0
451	03	3
452	05	5
453	01	1
454	07	7
455	01	1
456	06	6
457	69	OP
458	03	03
459	01	1
460	03	3
461	03	3
462	01	1
463	02	2
464	02	2
465	69	OP
466	04	04
467	69	OP
468	05	05
469	98	ADV
470	98	ADV
471	98	ADV
472	91	R/S
473	76	LBL
474	12	B
475	61	GTO
476	02	02
477	40	40
478	00	0
479	00	0

APPENDIX D

REDUCTION OF SLOPED DISTANCE TO SEA LEVEL DISTANCE USING RECIPROCAL VERTICAL ANGLE OBSERVATIONS

Purpose: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 112, Paragraph 48.

Observed or known sloped distances must be reduced to a horizontal (geodetic) length, usually at sea level, for use in the solution of triangulation data.

This program reduces sloped distances to sea level or ellipsoid lengths depending on the height used. It is designed for use with station-to-station or electronically measured sloped distance.

NOTES:

1. This program has been designed for use with the TI Printer (PC-100 Series). Simple modifications of the program are possible which will provide stop/output for a TI-59 calculator without a printer attachment.
2. Program constants are metric, therefore, input/output linear values must be in meters.
3. Angular values are input as one numerical entry with a decimal point placed between the degrees and minutes values.

INSTRUCTIONS:

1. Printer "ON" and, then Calculator "ON".
2. Load the four sides of the magnetic cards:

a. CLR, RST, 2, 2nd, OP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

b. 2; Enter Side 2.

c. 3; Enter Side 3.

d. 4; Enter Side 4.

Note: The numbers that are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and instructions.

4. Reference: EDME: "H1/H2 ABV STA."

a. If EDME measurement, enter heights of instruments/targets above their respective stations (1 or 2).

b. If sloped distance is station to station, enter zeroes for H1 and H2.

INPUT DATA:

1. Latitude (mean of the two stations): N (+), S(-).

2. Azimuth (from station 1 to station 2): Clockwise from 0^{o} North.

3. Vertical Angle at station 1 to station 2.

4. Vertical Angle at station 2 to station 1.

5. Height of theodolite above station 1, in meters.

6. Height of target above station 2, in meters.

7. Height of theodolite above station 2, in meters.

8. Height of target above station 1, in meters.

9. Sloped distance: station 1 to station 2, in meters.

10. Elevation of station 1, in meters.

11. EDME Heights (or zeroes if sloped distance is from station disk to station disk.

a. Height of instrument or reflectior/slave-unit above station 1, in meters.

b. Height of instrument oor reflector/slave-unit above station 2, in meters.

FORMULATION and COMPUTATION:

These formulas were derived by T. Vincenty for use with small calculators.

1. Angles are in radian measure in the following formulas.

2. Vertical angles are Positive upwards from the horizon.

3. Vertical angles are corrected for heights of theodolite (t) and targets (o) by (t-o)/L within the program.

$h_2 = h_1 + \Delta h = h_1 + L \sin V$
where $V = \frac{1}{2}(v_1 - v_2)$; ($v_1$ & v_2 = corrected angles).

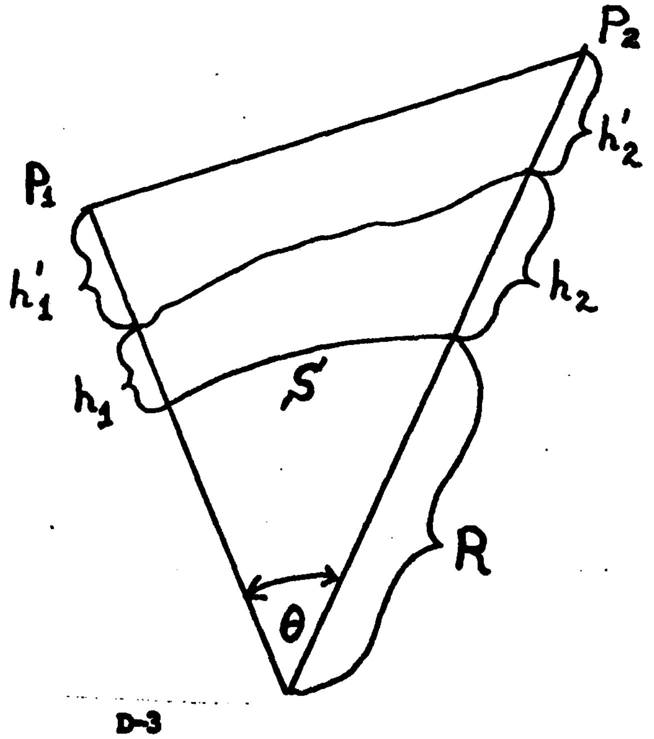
$S = s' - \Delta h'(\Delta h + \frac{1}{2}\Delta h')/s'$
where $\Delta h' = h'_2 - h'_1$

and where $$s' = \sqrt{\frac{L^2 - \Delta h^2}{1 + \frac{h_1 + h_2}{R}}}$$

Where $$R = 6400000 \left[1 - \left(\frac{\cos^2\phi}{295}\right)(1 + 2\cos^2\alpha)\right]$$

SBR "B" applies ellipsoid curvature correction and a correction to reduce the end points of the line to reference (ground) stations. These are combined in the following expression:

$$\text{Corr.} + \frac{S}{24R}\left[\frac{S^2}{R} - 12\,(h'_1 + h'_2)\right]$$



SAMPLE RUNS

```
EDM SL RECIP VER ANG
FORMAT AS FOLLOWS:

ANG D.MS/LINEAR MTRS
LAT N+ S-/AZ 0 DEG N

INPUT DATA IN ORDER:

LAT/ AZI/ VA 1/VA 2:


        30.
       100.
   -2.00012
    1.50006

  T1/  D2/  T2/  D1:


     10.01
      1.53
      1.65
     10.21
```

```
SLOPE DIS/ EL STA 1:


   30123.456
    2110.878

EDME: H1/H2 ABV STA


         10.32
          1.7


DEL H
     -999.122    MTRS

H2
     1111.756    MTRS

DIST     SL
    30098.997    MTRS


NEXT?

LAT/ AZI/ VA 1/VA 2:
```

PROGRAM LISTING

000	01	1
001	07	7
002	01	1
003	06	6
004	03	3
005	00	0
006	00	0
007	00	0
008	03	3
009	06	6
010	69	OP
011	01	01
012	02	2
013	07	7
014	00	0
015	00	0
016	03	3
017	05	5
018	01	1
019	07	7
020	01	1
021	05	5
022	69	OP
023	02	02
024	02	2
025	04	4
026	03	3
027	03	3
028	00	0
029	00	0
030	04	4
031	02	2
032	01	1
033	07	7
034	69	OP
035	03	03
036	03	3
037	05	5
038	00	0
039	00	0
040	01	1
041	03	3
042	03	3
043	01	1
044	02	2
045	02	2
046	69	OP
047	04	04
048	69	OP
049	05	05
050	02	2
051	01	1
052	03	3
053	02	2
054	03	3
055	05	5
056	03	3
057	00	0
058	01	1
059	03	3
060	69	OP
061	01	01
062	03	3
063	07	7
064	00	0
065	00	0
066	01	1
067	03	3
068	03	3
069	06	6
070	00	0
071	00	0
072	69	OP
073	02	02
074	02	2
075	01	1
076	03	3
077	02	2
078	02	2
079	07	7
080	02	2
081	07	7
082	03	3
083	04	4
084	69	OP
085	03	03
086	04	4
087	03	3
088	03	3
089	06	6
090	06	6
091	02	2
092	00	0
093	00	0
094	00	0
095	00	0
096	69	OP
097	04	04
098	69	OP
099	05	05
100	98	ADV
101	01	1
102	03	3
103	03	3
104	01	1
105	02	2
106	02	2
107	00	0
108	00	0
109	01	1
110	06	6
111	69	OP
112	01	01
113	04	4
114	00	0
115	03	3
116	00	0
117	03	3
118	06	6
119	06	6
120	03	3
121	02	2
122	07	7
123	69	OP
124	02	02
125	02	2
126	04	4
127	03	3
128	01	1
129	01	1
130	07	7
131	01	1
132	03	3
133	03	3
134	05	5
135	69	OP
136	03	03
137	03	3
138	00	0
139	03	3
140	07	7
141	03	3
142	05	5
143	03	3
144	06	6
145	69	OP
146	04	04
147	69	OP
148	05	05
149	02	2
150	07	7
151	01	1
152	03	3
153	03	3
154	07	7
155	00	0
156	00	0
157	03	3
158	01	1
159	69	OP
160	01	01
161	04	4
162	07	7
163	00	0
164	00	0
165	03	3
166	06	6
167	02	2
168	00	0
169	06	6
170	03	3
171	69	OP
172	02	02
173	01	1
174	03	3
175	04	4
176	06	6
177	00	0
178	00	0
179	00	0
180	01	1
181	00	0
182	00	0
183	69	OP
184	03	03
185	01	1
186	06	6
187	01	1
188	07	7
189	02	2
190	02	2
191	00	0
192	00	0
193	03	3
194	01	1
195	69	OP
196	04	04
197	69	OP
198	05	05
199	98	ADV

200	02	2	250	07	7	300	98	ADV	350	02	2
201	04	4	251	01	1	301	98	ADV	351	69	OP
202	03	3	252	03	3	302	91	R/S	352	04	04
203	01	1	253	03	3	303	99	PRT	353	69	OP
204	03	3	254	07	7	304	42	STO	354	05	05
205	03	3	255	06	6	305	09	09	355	98	ADV
206	04	4	256	03	3	306	91	R/S	356	98	ADV
207	01	1	257	00	0	307	99	PRT	357	98	ADV
208	03	3	258	00	0	308	42	STO	358	91	R/S
209	07	7	259	69	OP	309	10	10	359	99	PRT
210	69	OP	260	01	01	310	91	R/S	360	75	-
211	01	01	261	01	1	311	99	PRT	361	91	R/S
212	01	1	262	03	3	312	42	STO	362	99	PRT
213	06	6	263	04	4	313	11	11	363	75	-
214	01	1	264	06	6	314	91	R/S	364	91	R/S
215	03	3	265	02	2	315	99	PRT	365	99	PRT
216	03	3	266	04	4	316	42	STO	366	85	+
217	07	7	267	06	6	317	12	12	367	91	R/S
218	01	1	268	03	3	318	98	ADV	368	99	PRT
219	03	3	269	00	0	319	69	OP	369	95	=
220	69	OP	270	00	0	320	00	00	370	42	STO
221	02	02	271	69	OP	321	03	3	371	03	03
222	02	2	272	02	02	322	07	7	372	98	ADV
223	04	4	273	04	4	323	00	0	373	03	3
224	03	3	274	02	2	324	02	2	374	06	6
225	01	1	275	01	1	325	06	6	375	02	2
226	00	0	276	03	3	326	03	3	376	07	7
227	00	0	277	00	0	327	69	OP	377	03	3
228	03	3	278	00	0	328	01	01	378	02	2
229	02	2	279	00	0	329	03	3	379	03	3
230	69	OP	280	02	2	330	02	2	380	03	3
231	03	03	281	06	6	331	00	0	381	01	1
232	03	3	282	03	3	332	03	3	382	07	7
233	05	5	283	69	OP	333	06	6	383	69	OP
234	01	1	284	03	03	334	03	3	384	01	01
235	06	6	285	04	4	335	69	OP	385	01	1
236	01	1	286	02	2	336	02	02	386	06	6
237	07	7	287	01	1	337	03	3	387	02	2
238	03	3	288	03	3	338	07	7	388	04	4
239	05	5	289	00	0	339	00	0	389	03	3
240	06	6	290	00	0	340	03	3	390	06	6
241	02	2	291	00	0	341	06	6	391	06	6
242	69	OP	292	03	3	342	03	3	392	03	3
243	04	04	293	06	6	343	69	OP	393	69	OP
244	69	OP	294	02	2	344	03	03	394	02	02
245	05	05	295	69	OP	345	03	3	395	01	1
246	98	ADV	296	04	04	346	02	2	396	07	7
247	76	LBL	297	69	OP	347	00	0	397	02	2
248	87	IFF	298	05	05	348	02	2	398	07	7
249	02	2	299	98	ADV	349	06	6	399	00	0

400	00	0	450	00	0	500	11	11	550	01	1
401	03	3	451	02	2	501	19	D'	551	95	=
402	06	6	452	06	6	502	75	-	552	65	×
403	69	OP	453	03	3	503	53	(	553	06	6
404	03	03	454	02	2	504	43	RCL	554	04	4
405	03	3	455	03	3	505	12	12	555	00	0
406	07	7	456	69	OP	506	19	D'	556	00	0
407	01	1	457	02	02	507	85	+	557	00	0
408	03	3	458	03	3	508	43	RCL	558	00	0
409	00	0	459	00	0	509	03	03	559	00	0
410	00	0	460	00	0	510	95	=	560	95	=
411	00	0	461	01	1	511	55	÷	561	42	STO
412	02	2	462	03	3	512	02	2	562	01	01
413	06	6	463	01	1	513	95	=	563	43	RCL
414	02	2	464	04	4	514	38	SIN	564	04	04
415	69	OP	465	04	4	515	65	×	565	33	X^2
416	04	04	466	02	2	516	43	RCL	566	75	-
417	69	OP	467	69	OP	517	04	04	567	43	RCL
418	05	05	468	03	03	518	95	=	568	02	02
419	98	ADV	469	03	3	519	42	STO	569	33	X^2
420	98	ADV	470	06	6	520	02	02	570	95	=
421	98	ADV	471	03	3	521	44	SUM	571	55	÷
422	91	R/S	472	07	7	522	14	14	572	53	(
423	99	PRT	473	01	1	523	53	(	573	01	1
424	42	STO	474	03	3	524	43	RCL	574	85	+
425	04	04	475	00	0	525	09	09	575	53	(
426	22	INV	476	00	0	526	19	D'	576	43	RCL
427	49	PRD	477	69	OP	527	39	COS	577	14	14
428	03	03	478	04	04	528	33	X^2	578	85	+
429	91	R/S	479	69	OP	529	55	÷	579	43	RCL
430	99	PRT	480	05	05	530	02	2	580	05	05
431	42	STO	481	98	ADV	531	09	9	581	54	)
432	14	14	482	98	ADV	532	05	5	582	55	÷
433	42	STO	483	98	ADV	533	95	=	583	43	RCL
434	05	05	484	91	R/S	534	65	×	584	01	01
435	98	ADV	485	99	PRT	535	53	(	585	54	)
436	01	1	486	42	STO	536	01	1	586	95	=
437	07	7	487	06	06	537	85	+	587	34	√X
438	01	1	488	94	+/-	538	02	2	588	75	-
439	06	6	489	85	+	539	65	×	589	24	CE
440	03	3	490	91	R/S	540	53	(	590	35	1/X
441	00	0	491	99	PRT	541	43	RCL	591	65	×
442	01	1	492	44	SUM	542	10	10	592	43	RCL
443	07	7	493	06	06	543	19	D'	593	07	07
444	06	6	494	95	=	544	39	COS	594	65	×
445	02	2	495	42	STO	545	33	X^2	595	53	(
446	69	OP	496	07	07	546	54	)	596	43	RCL
447	01	01	497	98	ADV	547	95	=	597	02	02
448	02	2	498	53	(	548	94	+/-	598	85	+
449	03	3	499	43	RCL	549	85	+	599	43	RCL

600	07	07	650	17	B'	700	01	1	750	55	÷
601	55	÷	651	43	RCL	701	07	7	751	43	RCL
602	02	2	652	02	02	702	04	4	752	01	01
603	54	)	653	18	C'	703	04	4	753	75	-
604	95	=	654	02	2	704	03	3	754	01	1
605	42	STO	655	03	3	705	07	7	755	02	2
606	08	08	656	00	0	706	07	7	756	65	×
607	75	-	657	03	3	707	01	1	757	43	RCL
608	01	1	658	00	0	708	69	OP	758	06	06
609	00	0	659	00	0	709	01	01	759	54	)
610	00	0	660	00	0	710	69	OP	760	95	=
611	00	0	661	00	0	711	05	05	761	44	SUM
612	00	0	662	00	0	712	98	ADV	762	08	08
613	95	=	663	00	0	713	61	GTO	763	61	GTO
614	77	GE	664	69	OP	714	87	IFF	764	88	DMS
615	16	A'	665	01	01	715	76	LBL	765	76	LBL
616	43	RCL	666	69	OP	716	11	A	766	17	B'
617	15	15	667	05	05	717	22	INV	767	03	3
618	75	-	668	17	B'	718	58	FIX	768	00	0
619	02	2	669	43	RCL	719	47	CMS	769	03	3
620	95	=	670	14	14	720	25	CLR	770	07	7
621	77	GE	671	18	C'	721	70	RAD	771	03	3
622	16	A'	672	01	1	722	98	ADV	772	05	5
623	43	RCL	673	06	6	723	81	RST	773	03	3
624	16	16	674	02	2	724	76	LBL	774	06	6
625	75	-	675	04	4	725	19	D'	775	69	OP
626	02	2	676	03	3	726	88	DMS	776	04	04
627	95	=	677	06	6	727	65	×	777	92	RTN
628	77	GE	678	03	3	728	89	π	778	76	LBL
629	16	A'	679	07	7	729	55	÷	779	18	C'
630	76	LBL	680	00	0	730	01	1	780	58	FIX
631	88	DMS	681	00	0	731	08	8	781	03	03
632	98	ADV	682	69	OP	732	00	0	782	69	OP
633	98	ADV	683	01	01	733	54	)	783	06	06
634	69	OP	684	03	3	734	92	RTN	784	98	ADV
635	00	00	685	06	6	735	76	LBL	785	22	INV
636	01	1	686	02	2	736	16	A'	786	58	FIX
637	06	6	687	07	7	737	43	RCL	787	69	OP
638	01	1	688	69	OP	738	08	08	788	00	00
639	07	7	689	02	02	739	55	÷	789	92	RTN
640	02	2	690	69	OP	740	43	RCL	790	00	0
641	07	7	691	05	05	741	01	01	791	00	0
642	00	0	692	17	B'	742	55	÷	792	00	0
643	00	0	693	43	RCL	743	02	2	793	00	0
644	02	2	694	08	08	744	04	4	794	00	0
645	03	3	695	18	C'	745	65	×	795	00	0
646	69	OP	696	98	ADV	746	53	(	796	00	0
647	01	01	697	98	ADV	747	43	RCL	797	00	0
648	69	OP	698	03	3	748	08	08	798	00	0
649	05	05	699	01	1	749	33	X^2	799	00	0

APPENDIX E

THREE POINT (RESECTION) PROBLEM

<u>Purpose</u>: Reference TM 5-237, Surveying Computer's Manual, 1964 Pages 230/1 Paragraph 81.

This program will solve the unknown pearameters of a quadrilateral when three of the stations have known coordinates and horizontal directions are observed to them from the unknown station.

This solution is not to be confused with the inaccessible base or special angle problems.

<u>NOTES</u>:

1. The program is designed for use with the TI Printer (PC-100 Series).
2. The input values of the sides must be metric due to metric constants generated within the program.
3. Each of the two angular values, at the unknown (occupied) station between pairs of the three unknown stations, is input as one numerical entry with a decimal point between the degrees and minutes values.

<u>INSTRUCTIONS</u>:

1. Printer "ON" and, then, Calculator "ON".
2. Load the two sides of the magnetic cards:
   a. CLR, RST, 1, 2nd, OP, 17, 1, INV, 2nd, WRITE; Enter Side 1.
   b. 2; Enter Side 2.

Note: The underlined numbers may be replaced by zeroes. Refer to the operating instruction manual if further difficulty occurs.

3. Depress "A" for initialization and input.

4. Upon completion of the X, Y computation, another resection problem can be entered or: Depress "B" for the remaining parts of the figure.

INPUT DATA:

1. Side a, in meters.

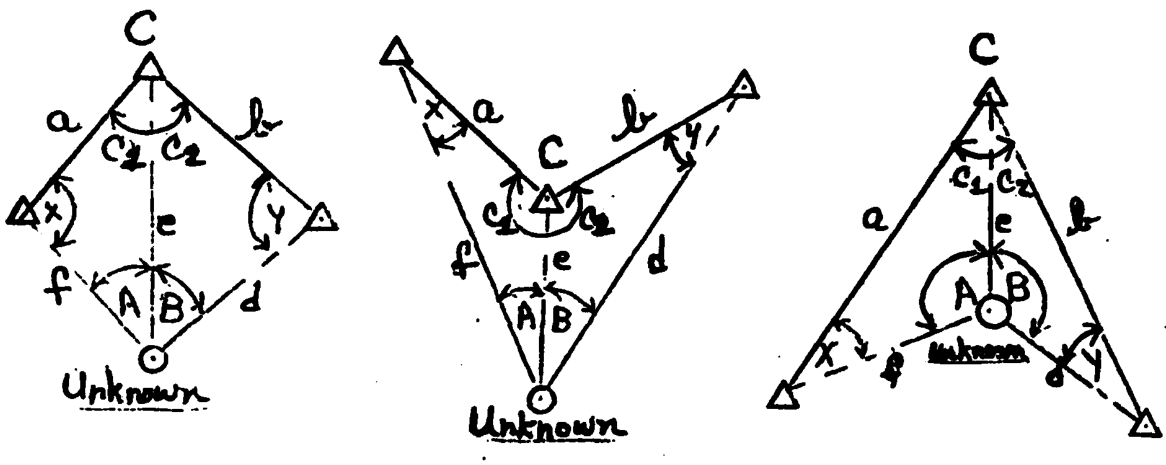
2. Side b, in meters.

3. Angle A at the unknown station which is opposite side a.

4. Angle B at the unknown station which is opposite side b.

5. Angle C at the known station (opposite the unknown station in the quadrilateral -- the middle one of three knowns).

FORMULATION and COMPUTATION:



$$1/2\ (x+y) = 180^{\circ} - 1/2\ (A+B+C)$$

$$\tan Z = \frac{b \sin A}{a \sin B}$$

$$\tan \frac{(x-y)}{2} = \tan \frac{(x+y)}{2} \tan (Z - 45^{\circ})$$

$$x = \frac{(x+y)}{2} + \frac{(x-y)}{2},\ y = \frac{(x+y)}{2} - \frac{(x-y)}{2}$$

SAMPLE RUNS

```
RESECTION:      INPUT

SIDES:A, B/ANGS:A, B, C


 4870.241
 9477.507

 30.41597
 64.27113
108.09343

 91.285506        =X
 65.121964        =Y

NEXT:A, B/ANGS:    B?


 57.490534        =C1
 50.202924        =C2

  8087.012        =D
  8073.751        =E
  9536.170        =F

RESECTION:      INPUT

SIDES:A, B/ANGS:A, B, C
```

000	25	CLR	050	05	05	100	43	RCL	150	05	5
001	98	ADV	051	65	×	101	02	02	151	01	1
002	98	ADV	052	43	RCL	102	58	FIX	152	07	7
003	98	ADV	053	08	08	103	06	06	153	03	3
004	91	R/S	054	88	DMS	104	98	ADV	154	06	6
005	42	STO	055	38	SIN	105	69	OP	155	01	1
006	04	04	056	55	÷	106	06	06	156	07	7
007	99	PRT	057	43	RCL	107	22	INV	157	01	1
008	91	R/S	058	04	04	108	58	FIX	158	05	5
009	42	STO	059	55	÷	109	06	6	159	69	OP
010	05	05	060	43	RCL	110	04	4	160	01	01
011	99	PRT	061	09	09	111	04	4	161	03	3
012	98	ADV	062	88	DMS	112	05	5	162	07	7
013	91	R/S	063	38	SIN	113	69	OP	163	02	2
014	42	STO	064	54	)	114	04	04	164	04	4
015	08	08	065	22	INV	115	43	RCL	165	03	3
016	99	PRT	066	30	TAN	116	01	01	166	02	2
017	91	R/S	067	75	-	117	58	FIX	167	03	3
018	42	STO	068	04	4	118	06	06	168	01	1
019	09	09	069	05	5	119	69	OP	169	06	6
020	99	PRT	070	54	)	120	06	06	170	02	2
021	91	R/S	071	30	TAN	121	22	INV	171	69	OP
022	99	PRT	072	95	=	122	58	FIX	172	02	02
023	88	DMS	073	22	INV	123	03	3	173	02	2
024	85	+	074	30	TAN	124	01	1	174	04	4
025	43	RCL	075	44	SUM	125	01	1	175	03	3
026	08	08	076	06	06	126	07	7	176	01	1
027	88	DMS	077	75	-	127	05	5	177	03	3
028	85	+	078	43	RCL	128	00	0	178	03	3
029	43	RCL	079	07	07	129	03	3	179	04	4
030	09	09	080	95	=	130	07	7	180	01	1
031	88	DMS	081	94	+/-	131	69	OP	181	03	3
032	95	=	082	42	STO	132	01	01	182	07	7
033	55	÷	083	07	07	133	01	1	183	69	OP
034	02	2	084	22	INV	134	04	4	184	04	04
035	75	-	085	88	DMS	135	07	7	185	98	ADV
036	01	1	086	42	STO	136	01	1	186	69	OP
037	08	8	087	01	01	137	69	OP	187	05	05
038	00	0	088	43	RCL	138	04	04	188	03	3
039	95	=	089	06	06	139	98	ADV	189	06	6
040	94	+/-	090	22	INV	140	69	OP	190	02	2
041	42	STO	091	88	DMS	141	05	05	191	04	4
042	06	06	092	42	STO	142	81	RST	192	01	1
043	42	STO	093	02	02	143	76	LBL	193	06	6
044	07	07	094	06	6	144	11	A	194	01	1
045	30	TAN	095	04	4	145	22	INV	195	07	7
046	65	×	096	04	4	146	58	FIX	196	03	3
047	53	(	097	04	4	147	69	OP	197	06	6
048	53	(	098	69	OP	148	00	00	198	69	OP
049	43	RCL	099	04	04	149	03	3	199	01	01

200	06	6	250	75	-	300	65	×	350	05	05
201	02	2	251	43	RCL	301	43	RCL	351	43	RCL
202	01	1	252	06	06	302	04	04	352	04	04
203	03	3	253	95	=	303	33	X²	353	65	×
204	05	5	254	42	STO	304	65	×	354	43	RCL
205	07	7	255	03	03	305	43	RCL	355	06	06
206	01	1	256	01	1	306	06	06	356	38	SIN
207	04	4	257	08	8	307	38	SIN	357	55	÷
208	06	6	258	00	0	308	55	÷	358	43	RCL
209	03	3	259	75	-	309	43	RCL	359	08	08
210	69	OP	260	43	RCL	310	08	08	360	38	SIN
211	02	02	261	09	09	311	38	SIN	361	95	=
212	01	1	262	88	DMS	312	55	÷	362	42	STO
213	03	3	263	42	STO	313	01	1	363	04	04
214	03	3	264	09	09	314	04	4	364	43	RCL
215	01	1	265	75	-	315	01	1	365	01	01
216	02	2	266	43	RCL	316	04	4	366	22	INV
217	02	2	267	07	07	317	08	8	367	88	DMS
218	03	3	268	95	=	318	52	EE	368	42	STO
219	06	6	269	42	STO	319	08	8	369	01	01
220	06	6	270	01	01	320	95	=	370	43	RCL
221	02	2	271	38	SIN	321	22	INV	371	03	03
222	69	OP	272	65	×	322	52	EE	372	22	INV
223	03	03	273	43	RCL	323	44	SUM	373	88	DMS
224	01	1	274	05	05	324	03	03	374	42	STO
225	03	3	275	33	X²	325	43	RCL	375	03	03
226	05	5	276	65	×	326	01	01	376	22	INV
227	07	7	277	43	RCL	327	38	SIN	377	58	FIX
228	01	1	278	07	07	328	65	×	378	06	6
229	04	4	279	38	SIN	329	43	RCL	379	04	4
230	05	5	280	55	÷	330	05	05	380	01	1
231	07	7	281	43	RCL	331	55	÷	381	05	5
232	01	1	282	09	09	332	43	RCL	382	00	0
233	05	5	283	38	SIN	333	09	09	383	02	2
234	69	OP	284	55	÷	334	38	SIN	384	69	OP
235	04	04	285	01	1	335	95	=	385	04	04
236	98	ADV	286	04	4	336	42	STO	386	43	RCL
237	69	OP	287	01	1	337	02	02	387	03	03
238	05	05	288	04	4	338	43	RCL	388	58	FIX
239	81	RST	289	08	8	339	03	03	389	06	06
240	25	CLR	290	52	EE	340	38	SIN	390	98	ADV
241	01	1	291	08	8	341	65	×	391	69	OP
242	08	8	292	95	=	342	43	RCL	392	06	06
243	00	0	293	22	INV	343	04	04	393	22	INV
244	75	-	294	52	EE	344	55	÷	394	58	FIX
245	43	RCL	295	44	SUM	345	43	RCL	395	06	6
246	08	08	296	01	01	346	08	08	396	04	4
247	88	DMS	297	43	RCL	347	38	SIN	397	01	1
248	42	STO	298	03	03	348	95	=	398	05	5
249	08	08	299	38	SIN	349	42	STO	399	00	0

400	03	3
401	69	OP
402	04	04
403	43	RCL
404	01	01
405	58	FIX
406	06	06
407	69	OP
408	06	06
409	22	INV
410	58	FIX
411	06	6
412	04	4
413	01	1
414	06	6
415	69	OP
416	04	04
417	43	RCL
418	02	02
419	58	FIX
420	03	03
421	98	ADV
422	69	OP
423	06	06
424	22	INV
425	58	FIX
426	06	6
427	04	4
428	01	1
429	07	7
430	69	OP
431	04	04
432	43	RCL
433	05	05
434	58	FIX
435	03	03
436	69	OP
437	06	06
438	22	INV
439	58	FIX
440	06	6
441	04	4
442	02	2
443	01	1
444	69	OP
445	04	04
446	43	RCL
447	04	04
448	58	FIX
449	03	03
450	69	OP
451	06	06
452	22	INV
453	58	FIX
454	11	A
455	76	LBL
456	12	B
457	22	INV
458	58	FIX
459	69	OP
460	00	00
461	61	GTO
462	02	02
463	40	40
464	00	0
465	00	0
466	00	0
467	00	0
468	00	0
469	00	0
470	00	0
471	00	0
472	00	0
473	00	0
474	00	0
475	00	0
476	00	0
477	00	0
478	00	0
479	00	0

APPENDIX F

TRANSFORMATION OF GEODETIC COORDINATES (NORTH AMERICAN DATUM 1927) TO STATE PLANE COORDINATES (LAMERT PROJECTION)

<u>Purpose</u>: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 366, Paragraphs 179/180.

The Lambert Conical Conformal type of projection is used with one or two standard parallels in areas extending mainly in an east-west direction. The projection provides very simple formulas for the conversion of geodetic to grid coordinates using the included constants. This projection is used for many states by the National Geodetic Survey (NGS) for the state plane grid systems in the United States.

<u>NOTES</u>:

1. This program is designed to be used with the TI Printer (PC-100 Series).
2. The listed program is written using the constants necessary to convert geodetic coordinates (North American Datum 1927) to state plan coordinates (Lambert Projection, California, Zone V).
3. The program listing/instructions can be modified for storage on magnetic cards for specific states or the constants can be input after initializing and depressing "E". See the attached listing of state/zone constants and codes.

<u>INSTRUCTIONS</u>:

1. Printer "ON" and, then, Calculator "ON".

2. Load the three sides of the magnetic cards:

   a. CLR, RST, 2, 2nd, OP, 17, 1, INV, 2nd, WRITE; Enter Side 1.

   b. 2; Enter Side 2.

   c. 3; Enter Side 3.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating instruction manual if difficulty occurs.

3. Depress "A" for initialization and:

   a. State, Zone, Geod/Grid.

   b. Constants, Storage Registers.

   c. Instructions for input of new constants and/or coordinates.

4. Output includes the "x" and "y" values and the mapping angle (or convergence angle) for use with known azimuths at the station.

INPUT DATA:

1. New constants, L1 through L11 (See attached listings).
2. Latitude: N (+), S(-).
3. Longitude: W(+), E(-).

FORMULATION and COMPUTATION:

1. Computations are performed in radians.

2. The equations used are from C & GS Publication 62-4 as modified by T. Vincenty for use in small calculators.

$$\sigma = (\omega_o - \phi + B \sin\phi \cos\phi (1 - C \cos^2\phi (1 - D \cos^2\phi)))/(A)$$

where: $A = 1.005104574$
$1/B = 195.90275$
$1/C = 234.8457$
$1/D = 190.62$

$$\beta = \sigma (1 + E \sigma^2 (1 + F \sigma (G \sigma - 1)))$$

where: E, F, and G are from C & GS Pub 62-4 values of L_9, L_{10}, and L_{11} as follows:

$$E = L_9 c^2 10^{-16} \qquad F = L_{10} c 10^{-8}/L_9 \qquad G = L_{11} c 10^{-8}/L_{10}$$

$$R = R_o + cm\beta \qquad \theta = (\lambda_o - \lambda) \sin\phi_o$$

$$x = x_o + R \sin\theta$$

$$y = R_1 - R + 2 R \sin^2(\theta / 2)$$

SAMPLE RUNS

```
CA 4.5 LAM GEOD/GRID

    2000000.        09
       7080.        10
 14.38132943        11
 30649424.27        12
 2099537.853        13
 .5700119219        14
 6.041365233        15
   594.51692        16
    57.39339        17
        999.        18
        0.91        19

E:NEW CONSTANTS   OR

INPUT LATITUDE, THEN
LONGITUDE DEG.MINSEC



 34.59365366
 16.59540661

 2300000.010      =X

  545000.001      =Y

MAP ANGLE

          0.      DEG
         34.      MIN
    15.42531      SEC

ANOTHER?
INPUT LATITUDE, THEN
LONGITUDE DEG.MINSEC
```

PROGRAM LISTING

000	98	ADV
001	98	ADV
002	02	2
003	52	EE
004	06	6
005	22	INV
006	52	EE
007	42	STO
008	09	09
009	07	7
010	00	0
011	08	8
012	00	0
013	42	STO
014	10	10
015	01	1
016	04	4
017	93	.
018	03	3
019	08	8
020	01	1
021	03	3
022	02	2
023	09	9
024	04	4
025	03	3
026	09	9
027	42	STO
028	11	11
029	03	3
030	00	0
031	06	6
032	04	4
033	09	9
034	04	4
035	02	2
036	04	4
037	93	.
038	02	2
039	07	7
040	42	STO
041	12	12
042	02	2
043	00	0
044	09	9
045	09	9
046	05	5
047	03	3
048	07	7
049	93	.
050	08	8
051	05	5
052	03	3
053	42	STO
054	13	13
055	93	.
056	05	5
057	07	7
058	00	0
059	00	0
060	01	1
061	01	1
062	09	9
063	02	2
064	01	1
065	09	9
066	42	STO
067	14	14
068	06	6
069	93	.
070	00	0
071	04	4
072	01	1
073	03	3
074	06	6
075	05	5
076	02	2
077	03	3
078	03	3
079	08	8
080	09	9
081	42	STO
082	15	15
083	05	5
084	09	9
085	04	4
086	93	.
087	05	5
088	01	1
089	06	6
090	09	9
091	02	2
092	42	STO
093	16	16
094	05	5
095	07	7
096	93	.
097	03	3
098	09	9
099	03	3
100	03	3
101	09	9
102	42	STO
103	17	17
104	09	9
105	09	9
106	09	9
107	42	STO
108	18	18
109	93	.
110	09	9
111	01	1
112	42	STO
113	19	19
114	22	INV
115	58	FIX
116	69	OP
117	00	00
118	01	1
119	05	5
120	01	1
121	03	3
122	00	0
123	00	0
124	00	0
125	05	5
126	04	4
127	00	0
128	69	OP
129	01	01
130	00	0
131	06	6
132	00	0
133	00	0
134	02	2
135	07	7
136	01	1
137	03	3
138	03	3
139	00	0
140	69	OP
141	02	02
142	02	2
143	02	2
144	01	1
145	07	7
146	03	3
147	02	2
148	01	1
149	06	6
150	69	OP
151	03	03
152	06	6
153	03	3
154	02	2
155	02	2
156	03	3
157	05	5
158	02	2
159	04	4
160	01	1
161	06	6
162	69	OP
163	04	04
164	69	OP
165	05	05
166	98	ADV
167	09	9
168	22	INV
169	90	LST
170	98	ADV
171	01	1
172	07	7
173	06	6
174	02	2
175	03	3
176	01	1
177	01	1
178	07	7
179	04	4
180	03	3
181	69	OP
182	01	01
183	01	1
184	05	5
185	03	3
186	02	2
187	03	3
188	01	1
189	03	3
190	06	6
191	69	OP
192	02	02
193	03	3
194	07	7
195	01	1
196	03	3
197	03	3
198	01	1
199	03	3

200	07	7	250	03	3	300	03	3	350	06	6
201	03	3	251	07	7	301	01	1	351	02	2
202	06	6	252	02	2	302	03	3	352	94	+/-
203	69	OP	253	03	3	303	06	6	353	85	+
204	03	03	254	01	1	304	01	1	354	01	1
205	03	3	255	07	7	305	07	7	355	95	=
206	02	2	256	03	3	306	01	1	356	65	×
207	03	3	257	01	1	307	05	5	357	18	C'
208	05	5	258	69	OP	308	69	OP	358	39	COS
209	69	OP	259	04	04	309	04	04	359	33	X^2
210	04	04	260	69	OP	310	69	OP	360	55	÷
211	69	OP	261	05	05	311	05	05	361	02	2
212	05	05	262	02	2	312	98	ADV	362	03	3
213	98	ADV	263	07	7	313	98	ADV	363	04	4
214	76	LBL	264	03	3	314	98	ADV	364	93	.
215	38	SIN	265	02	2	315	25	CLR	365	08	8
216	02	2	266	03	3	316	91	R/S	366	04	4
217	04	4	267	01	1	317	99	PRT	367	05	5
218	03	3	268	02	2	318	42	STO	368	07	7
219	01	1	269	02	2	319	02	02	369	94	+/-
220	03	3	270	02	2	320	91	R/S	370	85	+
221	03	3	271	04	4	321	99	PRT	371	01	1
222	04	4	272	69	OP	322	17	B'	372	95	=
223	01	1	273	01	01	323	94	+/-	373	65	×
224	03	3	274	03	3	324	42	STO	374	18	C'
225	07	7	275	07	7	325	03	03	375	38	SIN
226	69	OP	276	04	4	326	43	RCL	376	65	×
227	01	01	277	01	1	327	10	10	377	18	C'
228	02	2	278	01	1	328	55	÷	378	39	COS
229	07	7	279	06	6	329	06	6	379	55	÷
230	01	1	280	01	1	330	00	0	380	01	1
231	03	3	281	07	7	331	95	=	381	09	9
232	03	3	282	00	0	332	17	B'	382	05	5
233	07	7	283	00	0	333	44	SUM	383	93	.
234	02	2	284	69	OP	334	03	03	384	09	9
235	04	4	285	02	02	335	43	RCL	385	00	0
236	69	OP	286	01	1	336	14	14	386	02	2
237	02	02	287	06	6	337	49	PRD	387	07	7
238	03	3	288	01	1	338	03	03	388	05	5
239	07	7	289	07	7	339	18	C'	389	75	-
240	04	4	290	02	2	340	17	B'	390	18	C'
241	01	1	291	02	2	341	42	STO	391	85	+
242	01	1	292	04	4	342	02	02	392	43	RCL
243	06	6	293	00	0	343	39	COS	393	15	15
244	01	1	294	03	3	344	33	X^2	394	19	D'
245	07	7	295	00	0	345	55	÷	395	35	1/X
246	05	5	296	69	OP	346	01	1	396	95	=
247	07	7	297	03	03	347	09	9	397	55	÷
248	69	OP	298	02	2	348	00	0	398	01	1
249	03	03	299	04	4	349	93	.	399	93	.

400	00	0
401	00	0
402	05	5
403	01	1
404	00	0
405	04	4
406	05	5
407	07	7
408	04	4
409	95	=
410	42	STO
411	02	02
412	19	D'
413	55	÷
414	43	RCL
415	18	18
416	75	-
417	01	1
418	95	=
419	65	×
420	18	C'
421	19	D'
422	55	÷
423	43	RCL
424	17	17
425	85	+
426	01	1
427	95	=
428	65	×
429	18	C'
430	33	X^2
431	19	D'
432	19	D'
433	55	÷
434	43	RCL
435	16	16
436	85	+
437	01	1
438	95	=
439	65	×
440	18	C'
441	65	×
442	43	RCL
443	13	13
444	19	D'
445	85	+
446	43	RCL
447	11	11
448	65	×
449	43	RCL
450	13	13
451	95	=
452	42	STO
453	02	02
454	65	×
455	43	RCL
456	03	03
457	38	SIN
458	85	+
459	43	RCL
460	09	09
461	95	=
462	42	STO
463	04	04
464	06	6
465	04	4
466	04	4
467	04	4
468	00	0
469	00	0
470	69	OP
471	04	04
472	43	RCL
473	04	04
474	98	ADV
475	58	FIX
476	03	03
477	69	OP
478	06	06
479	22	INV
480	58	FIX
481	43	RCL
482	03	03
483	55	÷
484	02	2
485	95	=
486	38	SIN
487	33	X^2
488	65	×
489	18	C'
490	65	×
491	02	2
492	75	-
493	18	C'
494	85	+
495	43	RCL
496	12	12
497	95	=
498	42	STO
499	02	02
500	06	6
501	04	4
502	04	4
503	05	5
504	00	0
505	00	0
506	69	OP
507	04	04
508	18	C'
509	58	FIX
510	03	03
511	98	ADV
512	69	OP
513	06	06
514	22	INV
515	58	FIX
516	69	OP
517	00	00
518	03	3
519	00	0
520	01	1
521	03	3
522	03	3
523	03	3
524	00	0
525	00	0
526	01	1
527	03	3
528	69	OP
529	01	01
530	03	3
531	01	1
532	02	2
533	02	2
534	02	2
535	07	7
536	01	1
537	07	7
538	00	0
539	00	0
540	69	OP
541	02	02
542	98	ADV
543	69	OP
544	05	05
545	43	RCL
546	03	03
547	65	×
548	01	1
549	08	8
550	00	0
551	55	÷
552	89	π
553	95	=
554	22	INV
555	88	DMS
556	42	STO
557	03	03
558	01	1
559	06	6
560	01	1
561	07	7
562	02	2
563	02	2
564	69	OP
565	04	04
566	43	RCL
567	03	03
568	59	INT
569	22	INV
570	44	SUM
571	03	03
572	98	ADV
573	69	OP
574	06	06
575	03	3
576	00	0
577	02	2
578	04	4
579	03	3
580	01	1
581	69	OP
582	04	04
583	43	RCL
584	03	03
585	19	D'
586	19	D'
587	95	=
588	42	STO
589	03	03
590	59	INT
591	22	INV
592	44	SUM
593	03	03
594	69	OP
595	06	06
596	03	3
597	06	6
598	01	1
599	07	7

600	01	1	650	92	RTN	700	91	R/S	750	55	÷
601	05	5	651	76	LBL	701	99	PRT	751	43	RCL
602	69	OP	652	19	D'	702	72	ST*	752	01	01
603	04	04	653	65	×	703	00	00	753	75	-
604	43	RCL	654	01	1	704	69	OP	754	01	1
605	03	03	655	00	0	705	20	20	755	02	2
606	19	D'	656	92	RTN	706	97	DSZ	756	65	×
607	19	D'	657	76	LBL	707	01	01	757	43	RCL
608	95	=	658	17	B'	708	33	X²	758	06	06
609	58	FIX	659	88	DMS	709	61	GTO	759	54	)
610	05	05	660	75	-	710	38	SIN	760	95	=
611	69	OP	661	01	1	711	92	RTN	761	44	SUM
612	06	06	662	00	0	712	76	LBL	762	08	08
613	22	INV	663	00	0	713	11	A	763	61	GTO
614	58	FIX	664	95	=	714	70	RAD	764	88	DMS
615	69	OP	665	77	GE	715	22	INV	765	76	LBL
616	00	00	666	34	ΓX	716	58	FIX	766	17	B'
617	01	1	667	85	+	717	81	RST	767	03	3
618	03	3	668	01	1	718	00	0	768	00	0
619	03	3	669	00	0	719	00	0	769	03	3
620	01	1	670	00	0	720	25	CLR	770	07	7
621	03	3	671	95	=	721	70	RAD	771	03	3
622	02	2	672	76	LBL	722	98	ADV	772	05	5
623	03	3	673	34	ΓX	723	81	RST	773	03	3
624	07	7	674	65	×	724	76	LBL	774	06	6
625	02	2	675	89	π	725	19	D'	775	69	OP
626	03	3	676	55	÷	726	88	DMS	776	04	04
627	69	OP	677	01	1	727	65	×	777	92	RTN
628	01	01	678	08	8	728	89	π	778	76	LBL
629	01	1	679	00	0	729	55	÷	779	18	C'
630	07	7	680	95	=	730	01	1	780	58	FIX
631	03	3	681	92	RTN	731	08	8	781	03	03
632	05	5	682	76	LBL	732	00	0	782	69	OP
633	07	7	683	15	E	733	54	)	783	06	06
634	01	1	684	09	9	734	92	RTN	784	98	ADV
635	00	0	685	42	STO	735	76	LBL	785	22	INV
636	00	0	686	00	00	736	16	A'	786	58	FIX
637	00	0	687	01	1	737	43	RCL	787	69	OP
638	00	0	688	01	1	738	08	08	788	00	00
639	69	OP	689	42	STO	739	55	÷	789	92	RTN
640	02	02	690	01	01	740	43	RCL	790	00	0
641	98	ADV	691	76	LBL	741	01	01	791	00	0
642	69	OP	692	33	X²	742	55	÷	792	00	0
643	05	05	693	43	RCL	743	02	2	793	00	0
644	61	GTO	694	00	00	744	04	4	794	00	0
645	38	SIN	695	98	ADV	745	65	×	795	00	0
646	76	LBL	696	99	PRT	746	53	(	796	00	0
647	18	C'	697	75	-	747	43	RCL	797	00	0
648	43	RCL	698	08	8	748	08	08	798	00	0
649	02	02	699	95	=	749	33	X²	799	00	0

APPENDIX

Lambert Projection Constants

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Alaska*	10 50.0	3 000 000 10 560	7.5707 74528 16 564 628.77	2 099 382.342 0.79692 23940	9.19729 71118 597.02694	30.58736 6.40	-106
Arkansas	North 3.1	2 000 000 5 520	13.9445 87488 29 732 882.87	2 099 566.849 0.58189 91407	6.18653 07455 594.62757	55.65314 999	0.93
Arkansas	South 3.2	2 000 000 5 520	14.7718 94984 31 511 724.20	2 099 530.173 0.55969 06871	5.91651 81558 594.47485	58.94981 999	0.88
California	I 4.1	2 000 000 7 320	11.5482 67459 24 792 436.23	2 099 480.129 0.65388 43192	7.10187 84606 595.34551	46.10317 999	1.13
California	II 4.2	2 000 000 7 320	12.2865 33640 26 312 257.65	2 099 522.214 0.63046 79732	6.79664 27326 595.10340	49.04553 999	1.06
California	III 4.3	2 000 000 7 230	12.8872 57544 27 512 992.04	2 099 552.659 0.61223 20427	6.56416 00543 594.91922	51.43955 999	1.01
California	IV 4.4	2 000 000 7 140	13.4228 96887 28 652 931.96	2 099 576.982 0.59658 71443	6.36804 49092 594.76790	53.57406 999	0.97
California	V 4.5	2 000 000 7 080	14.3813 29439 30 649 424.27	2 099 537.853 0.57001 19219	6.04136 52389 594.51692	57.39339 999	0.91
California	VI 4.6	2 000 000 6 975	15.1678 86218 32 271 267.72	2 099 605.078 0.54951 75982	5.79450 10359 594.33154	60.32780 999	0.86
California	VII 4.7	4 186 692.58 7 100	14.7124 42842 35 055 396.31	2 099 677.289 0.56124 32071	5.93522 87569 594.44057	58.71246 999	0.88
Colorado	North 5.1	2 000 000 6 330	11.7888 03056 25 086 068.20	2 099 610.755 0.64613 34829	6.99996 40610 595.26427	47.06188 999	1.11
Colorado	Central 5.2	2 000 000 6 330	12.2793 79233 26 243 052.74	2 099 566.796 0.63068 95773	6.79949 49875 595.10497	49.01733 999	1.06

* In eastern hemisphere use L2 = -11040 and enter longitude as negative east of Greenwich.

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Colorado	South 5.3	2 000 000 6 330	12.8487 82891 27 402 231.82	2 099 586.717 0.61337 80528	6.57864 36904 594.93171	51.28621 999	1.01
Connecticut	6.0	600 000 4 365	11.2680 94062 23 914 389.02	2 099 665.962 0.66305 94147	8.27090 58758 595.44397	44.98648 999	1.16
Florida	North 9.3	2 000 000 5 070	17.1606 79006 36 454 924.53	2 099 593.089 0.50252 59000	5.24307 17084 593.93314	68.46860 999	0.76
Iowa	North 14.1	2 000 000 5 610	10.8292 50755 23 162 461.59	2 099 586.652 0.67774 45518	7.42152 89284 595.60346	43.23744 999	1.21
Iowa	South 14.2	2 000 000 5 610	11.4005 83645 24 374 096.67	2 099 592.955 0.65870 10213	7.16567 22121 595.39708	45.51460 999	1.15
Kansas	North 15.1	2 000 000 5 880	12.2141 49149 25 979 068.57	2 099 610.772 0.63271 48646	6.82559 35033 595.12526	48.74582 999	1.07
Kansas	South 15.2	2 000 000 5 910	12.8102 73201 27 351 521.50	2 099 566.813 0.61452 81068	6.59319 50618 594.94263	51.13276 999	1.02
Kentucky	North 16.1	2 000 000 5 055	12.5602 72222 26 724 051.82	2 099 621.745 0.62206 72671	6.68900 50779 595.01754	50.13644 999	1.04
Kentucky	South 16.2	2 000 000 5 145	13.0825 08590 27 832 235.64	2 099 586.678 0.60646 23718	6.49148 93225 594.86305	52.21762 999	1.00
Louisiana	North 17.1	2 000 000 5 550	16.0153 41985 34 079 629.33	2 099 522.345 0.52870 06734	5.54785 31326 594.15095	63.90452 999	0.81
Louisiana	South 17.2	2 000 000 5 480	17.2758 29558 36 756 553.45	2 099 545.450 0.50001 26971	5.2141C 08548 593.91292	68.92709 999	0.75
Louisiana	Offshore 17.3	2 000 000 5 480	19.5723 41939 41 576 762.39	2 099 480.464 0.45400 68519	4.69199 30345 593.56012	80.02091 4.33	1.51

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Maryland	 19.0	800 000 4 620	12.3783 21478 26 369 112.76	2 099 596.059 0.62763 41196	6.76022 71189 595.07374	49.41137 999	1.05
Massachusetts	Mainland 20.1	600 000 4 290	11.0076 57990 23 549 477.32	2 099 626.929 0.67172 86561	7.34005 64125 595.53621	43.94857 999	1.19
Massachusetts	Island 20.2	200 000 4 230	11.3276 65409 23 924 398.02	2 099 698.180 0.66109 53994	7.19751 84389 595.42209	45.22407 999	1.15
Michigan	North 21.6	2 000 000 5 220	9.5455 94618 20 589 420.09	2 099 577.552 0.72278 99381	8.05286 43674 596.11375	38.68598 6.20	7.89
Michigan	Central 21.7	2 000 000 5 060	10.0027 30252 21 594 768.40	2 099 598.279 0.70640 74180	7.81862 74014 595.92424	40.56489 6.08	6.61
Michigan	South 21.8	2 000 000 5 060	10.7472 84488 23 069 597.22	2 099 586.043 0.68052 92633	7.45945 18656 595.63317	43.62769 6.00	4.95
Minnesota	North 22.1	2 000 000 5 586	9.0423 16733 19 471 398.75	2 099 497.306 0.74121 96637	8.32350 57512 596.33159	36.11389 999	1.45
Minnesota	Central 22.2	2 000 000 5 655	9.5290 88412 20 493 457.15	2 099 537.632 0.72338 80702	8.06152 53999 596.12002	38.05459 999	1.37
Minnesota	South 22.3	2 000 000 5 640	10.1579 53472 21 874 349.14	2 099 537.679 0.70092 77824	7.74151 09282 595.86162	40.56153 999	1.29
Montana	North 25.1	2 000 000 6 570	8.9012 80761 19 157 874.26	2 099 641.490 0.74645 18080	8.40183 14127 596.39431	35.55153 999	1.47
Montana	Central 25.2	2 000 000 6 570	9.2558 18806 19 919 806.36	2 099 537.617 0.73335 38278	8.20702 13948 596.23754	36.96514 999	1.41
Montana	South 25.3	2 000 000 6 570	9.7644 74280 21 096 820.93	2 099 514.006 0.71490 12442	7.93936 49928 596.02133	38.99298 999	1.34

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Nebraska	North 26.1	2 000 000 6 000	10.9563 97056 23 368 977.46	2 099 626.928 0.63735 07906	7.36331 64959 595.55498	43.74423 999	1.19
Nebraska	South 26.2	2 000 000 5 970	11.4808 89640 24 590 781.86	2 099 537.738 0.65607 64003	7.13086 65818 595.36895	45.83467 999	1.14
New York	Long Island 31.4	2 000 000 4 440	11.5421 76825 24 462 545.30	2 099 690.654 0.65408 20950	7.10449 08273 595.34864	46.07893 999	1.13
North Carolina	32.0	2 000 000 4 740	14.1166 91879 30.183 611.25	2 099 433.757 0.57717 07700	6.12860 74841 594.58393	56.33878 999	0.92
North Dakota	North 33.1	2 000 000 6 030	8.9636 82598 19 215 516.01	2 099 566.651 0.74413 33961	8.36703 98661 596.36765	35.80031 999	1.46
North Dakota	South 33.2	2 000 000 6 030	9.3643 26488 20 086 977.18	2 099 566.671 0.72938 26040	8.14877 03843 596.19052	37.39771 999	1.40
Ohio	North 34.1	2 000 000 4 950	11.4541 06100 24 559 158.47	2 099 573.576 0.65695 03193	7.14244 39257 595.37833	45.72791 999	1.14
Ohio	South 34.2	2 000 000 4 950	12.1562 57795 26 027 071.12	2 099 566.844 0.63451 95439	6.84889 67952 595.14400	48.52639 999	1.07
Oklahoma	North 35.1	2 000 000 5 880	13.6492 91606 29 082 831.70	2 099 586.740 0.59014 70744	6.28815 79862 594.70553	54.47632 999	0.95
Oklahoma	South 35.2	2 000 000 5 880	14.4709 99525 30 838 032.96	2 099 566.862 0.56761 66827	6.01229 51464 594.49510	57.75084 999	0.90
Oregon	North 36.1	2 000 000 7 230	9.9244 81684 21 383 852.48	2 099 480.014 0.70918 60222	7.85796 14005 595.95556	39.63095 999	1.32
Oregon	South 36.2	2 000 000 7 230	10.6413 53445 22 888 667.15	2 099 480.066 0.68414 73833	7.50892 71822 595.67384	42.48847 999	1.23

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Pennsylvania	North 37.1	2 000 000 4 665	11.3141 69244 24 211 050.37	2 099 610.741 0.66153 97363	7.20343 82515 595.42678	45.15854 999	1.15
Pennsylvania	South 37.2	2 000 000 4 665	11.7058 53283 24 984 826.43	2 099 616.327 0.64879 31663	7.03483 46103 595.29239	46.73136 999	1.11
South Carolina	North 39.1	2 000 000 4 860	14.5886 44817 31 127 724.75	2 099 586.762 0.56449 73800	5.97452 58161 594.46706	58.21947 999	0.89
South Carolina	South 39.2	2 000 000 4 860	15.3613 74673 32 676 887.64	2 099 559.902 0.54465 15700	5.73648 89600 594.28950	61.74753 999	0.84
South Dakota	North 40.1	2 000 000 6 000	9.9652 16243 21 366 697.03	2 099 573.515 0.70773 81841	7.83744 62836 595.93990	39.79320 999	1.31
South Dakota	South 40.2	2 000 000 6 020	10.4755 96174 22 461 937.05	2 099 505.865 0.68985 19579	7.58740 89499 595.73842	41.82781 999	1.25
Tennessee	41.0	2 000 000 5 160	13.8170 73482 29 535 149.91	2 099 593.024 0.58543 97296	6.23006 34541 594.66031	55.14496 999	0.94
Texas	North 42.1	2 000 000 6 090	14.0303 44192 29 972 959.94	2 099 514.231 0.57953 58654	6.15754 99858 594.60575	55.99482 999	0.93
Texas	N.Central 42.2	2 000 000 5 850	15.3316 61298 32 691 654.54	2 099 433.907 0.54539 44146	5.74533 06210 594.29572	61.18035 999	0.85
Texas	Central 42.3	2 000 000 6 020	16.6003 72791 35 337 121.23	2 099 453.060 0.51505 88857	5.38829 78793 594.03580	66.23589 999	0.78
Texas	S.Central 42.4	2 000 000 5 940	17.7485 26687 37 807 440.38	2 099 414.214 0.48991 26408	5.09816.44664 593.83362	70.81092 999	0.73
Texas	South 42.5	2 000 000 5 910	19.5723 41939 41 576 762.39	2 099 480.464 0.45400 68519	4.69199 30345 593.56012	78.07853 999	0.66

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Utah	North 43.1	2 000 000 6 690	11.3806 20205 24 229 110.29	2 099 610.744 0.65935 54910	7.17436 79884 595.40334	45.43514 999	1.15
Utah	Central 43.2	2 000 000 6 690	11.9634 71949 25 664 114.42	2 099 488.916 0.64057 85926	6.92746 87843 595.20647	47.75829 999	1.09
Utah	South 43.3	2 000 000 6 690	12.8719 59904 27 432 812.88	2 099 599.094 0.61268 73424	6.56991 23007 594.92390	51.37860 999	1.01
Virginia	North 45.1	2 000 000 4 710	12.4929 92805 26 576 444.45	2 099 592.988 0.62411 78597	6.71519 24430 595.03784	49.86899 999	1.04
Virginia	South 45.2	2 000 000 4 710	13.0667 62019 27 811 312.71	2 099 586.724 0.60692 48249	6.49729 89409 594.86773	52.15482 999	1.00
Washington	North 46.1	2 000 000 7 250	8.9532 57623 19 205 863.43	2 099 580.115 0.74452 03390	8.37283 68522 596.37236	35.75876 999	1.46
Washington	South 46.2	2 000 000 7 230	9.4462 70779 20 289 119.60	2 099 522.021 0.72639 57947	8.01519 85672 596.15605	37.72440 999	1.39
West Virginia	North 47.1	2 000 000 4 770	12.0524 41881 25 715 126.55	2 099 576.946 0.63777 29696	6.89102 19040 595.17836	48.11250 999	1.08
West Virginia	South 47.2	2 000 000 4 860	12.6881 39167 27 070 620.78	2 099 545.339 0.61819 53936	6.63970 86618 594.97852	50,64632 999	1.03
Wisconsin	North 48.1	2 000 000 5 400	9.5848 07314 20 489 179.67	2 099 586.605 0.72137 07913	8.03234 65428 596.09808	38.27671 999	1.36
Wisconsin	Central 48.2	2 000 000 5 400	10.0261 85452 21 430 913.91	2 099 576.862 0.70557 66312	7.80689 71899 595.91485	40.03631 999	1.30
Wisconsin	South 48.3	2 000 000 5 400	10.5552 75906 22 672 134.66	2 099 559,732 0.68710 32423	7.54951 94619 595.70670	42.14537 999	1.24

APPENDIX G

TRANSFORMATION OF STATE PLANE COORDINATES (LAMBERT PROJECTION) TO GEODETIC COORDINATES (NORTH AMERICAN DATUM 1927)

<u>Purpose</u>: Reference TM 5-237, Surveying Computer's Manual, 1964 Page 366, Paragraphs 179/180.

The Lambert Conical Conformal type of projection is used with one or two standard parallels in areas extending mainly in an east-west direction. The projection provides very simple formulas for the conversion of grid to geodetic coordinates using the included constants. This projection is used for many states by the National Geodetic Survey (NGS) for the state plane grid systems in the United States.

<u>NOTES</u>:

1. This program is designed to be used with the TI Printer (PC-100 Series).
2. The listed program is written using the constants necessary to convert state plane coordinates (Lambert Projection, California, Zone V) to geodetic coordinates (North American Datum 1927).
3. The program listing/instructions can be modified for storage on magnetic cards for specific states or the constants can be input after initializing and depressing "E". See the attached listing of state/zone constants and codes.

<u>INSTRUCTIONS</u>:

1. Printer "ON" and, then, Calculator "ON".

2. Load the three sides of the magnetic cards:

a. CLR, RST, 2, 2nd, OP, 17, 1, 2nd, WRITE; Enter Side 1.

b. 2; Enter Side 2.

c. 3; Enter Side 3.

Note: The numbers which are underlined may be replaced by zeroes. Refer to operating insturction manual if difficulty occurs.

3. Depress "A" for initialization and:

a. State, Zone, Grid/Geod.

b. Constants, Storage Registers.

c. Instructions for input of new constants and/or coordinates.

4. Output includes the latitude and longitude values and the mapping angle (or convergence angle) for use with known azimuths at the station.

INPUT DATA:

1. New Constants, L1 through L11 (see attached listings).

2. Grid coordinate "x", in feet.

3. Grid coordinate "y", in feet.

FORMULATION and COMPUTATION:

1. Computations are performed in radians.

2. The equations used are from C & CS Publication 62-4 as modified by T. Vincenty for use in small calculators.

$$\theta = \arctan (x - x_o)/(R_1 - y)$$

$$\lambda = \lambda_o - (\theta/(\sin \phi_o))$$

$$R = (R_1 - y)/\cos \theta$$

$$\beta = (R_1 - R_o - y + 2R \sin^2 (\theta/2))/cm$$

$$\sigma = \beta(1 + E \beta^2 (F\beta (1 + H\beta) - 1))$$

Where: E, F, and H are from C & GS Pub 62-4 values of L_9, L_{10}, abd L_{11} as follows:

$$E = L_9 c^2 10^{-16} \quad F = L_{10} c10^{-8}/L_9$$

$$H = L_9 (3 L_9^2 - L_{11}) c 10^{-8}/L_{10}$$

$$\omega = \omega_0 - 1.005104574 \sigma$$

$$\phi = \omega + B' \sin \omega \cos \omega (1 + C' \cos^2 \omega (1 + D' \cos^2 \omega))$$

Where: $1/B' = 196.90273$
$1/C' = 169.1567$
$1/D' = 121.64$

SAMPLE RUNS

```
CA 4.5 LAM GRID/GEOD

     2000000.        09
        7080.        10
 14.38132943         11
 30649424.27         12
 2099537.853         13
 .5700119219         14
 6.041365233         15
   594.51692         16
    57.39339         17
        999.         18
        0.91         19

E:NEW CONSTANTS   OR

INPUT X IN FEET, THEN
      Y IN FEET



    2300000.
     545000.

LATITUDE
         34.      DEG
         59.      MIN
    36.53660      SEC

LONGITUDE
        116.      DEG
         59.      MIN
    54.06612      SEC

MAP ANGLE
          0.      DEG
         34.      MIN
    15.42525      SEC

ANOTHER?

INPUT X IN FEET, THEN
      Y IN FEET
```

000	98	ADV	050	08	8	100	03	3	150	69	OP
001	98	ADV	051	05	5	101	09	9	151	03	03
002	02	2	052	03	3	102	42	STO	152	06	6
003	52	EE	053	42	STO	103	17	17	153	03	3
004	06	6	054	13	13	104	09	9	154	02	2
005	22	INV	055	93	.	105	09	9	155	02	2
006	52	EE	056	05	5	106	09	9	156	01	1
007	42	STO	057	07	7	107	42	STO	157	07	7
008	09	09	058	00	0	108	18	18	158	03	3
009	07	7	059	00	0	109	93	.	159	02	2
010	00	0	060	01	1	110	09	9	160	01	1
011	08	8	061	01	1	111	01	1	161	06	6
012	00	0	062	09	9	112	42	STO	162	69	OP
013	42	STO	063	02	2	113	19	19	163	04	04
014	10	10	064	01	1	114	22	INV	164	69	OP
015	01	1	065	09	9	115	58	FIX	165	05	05
016	04	4	066	42	STO	116	69	OP	166	98	ADV
017	93	.	067	14	14	117	00	00	167	09	9
018	03	3	068	06	6	118	01	1	168	22	INV
019	08	8	069	93	.	119	05	5	169	90	LST
020	01	1	070	00	0	120	01	1	170	98	ADV
021	03	3	071	04	4	121	03	3	171	01	1
022	02	2	072	01	1	122	00	0	172	07	7
023	09	9	073	03	3	123	00	0	173	06	6
024	04	4	074	06	6	124	00	0	174	02	2
025	03	3	075	05	5	125	05	5	175	03	3
026	09	9	076	02	2	126	04	4	176	01	1
027	42	STO	077	03	3	127	00	0	177	01	1
028	11	11	078	03	3	128	69	OP	178	07	7
029	03	3	079	08	8	129	01	01	179	04	4
030	00	0	080	09	9	130	00	0	180	03	3
031	06	6	081	42	STO	131	06	6	181	69	OP
032	04	4	082	15	15	132	00	0	182	01	01
033	09	9	083	05	5	133	00	0	183	01	1
034	04	4	084	09	9	134	02	2	184	05	5
035	02	2	085	04	4	135	07	7	185	03	3
036	04	4	086	93	.	136	01	1	186	02	2
037	93	.	087	05	5	137	03	3	187	03	3
038	02	2	088	01	1	138	03	3	188	01	1
039	07	7	089	06	6	139	00	0	189	03	3
040	42	STO	090	09	9	140	69	OP	190	06	6
041	12	12	091	02	2	141	02	02	191	69	OP
042	02	2	092	42	STO	142	02	2	192	02	02
043	00	0	093	16	16	143	02	2	193	03	3
044	09	9	094	05	5	144	03	3	194	07	7
045	09	9	095	07	7	145	05	5	195	01	1
046	05	5	096	93	.	146	02	2	196	03	3
047	03	3	097	03	3	147	04	4	197	03	3
048	07	7	098	09	9	148	01	1	198	01	1
049	93	.	099	03	3	149	06	6	199	03	3

200	07	7	250	07	7	300	42	STO	350	43	RCL
201	03	3	251	02	2	301	03	03	351	19	19
202	06	6	252	03	3	302	42	STO	352	85	+
203	69	OP	253	01	1	303	04	04	353	01	1
204	03	03	254	07	7	304	35	1/X	354	95	=
205	03	3	255	03	3	305	65	×	355	16	A'
206	02	2	256	01	1	306	53	(	356	19	D'
207	03	3	257	69	OP	307	18	C'	357	55	÷
208	05	5	258	04	04	308	75	-	358	43	RCL
209	69	OP	259	98	ADV	309	43	RCL	359	17	17
210	04	04	260	69	OP	310	09	09	360	75	-
211	69	OP	261	05	05	311	54	)	361	01	1
212	05	05	262	69	OP	312	95	=	362	95	=
213	76	LBL	263	00	00	313	22	INV	363	16	A'
214	38	SIN	264	04	4	314	30	TAN	364	33	X²
215	02	2	265	05	5	315	42	STO	365	19	D'
216	04	4	266	00	0	316	02	02	366	19	D'
217	03	3	267	00	0	317	39	COS	367	55	÷
218	01	1	268	02	2	318	22	INV	368	43	RCL
219	03	3	269	04	4	319	49	PRD	369	16	16
220	03	3	270	03	3	320	03	03	370	85	+
221	04	4	271	01	1	321	18	C'	371	01	1
222	01	1	272	69	OP	322	55	÷	372	95	=
223	03	3	273	02	02	323	02	2	373	16	A'
224	07	7	274	02	2	324	95	=	374	95	=
225	69	OP	275	01	1	325	38	SIN	375	65	×
226	01	01	276	01	1	326	33	X²	376	01	1
227	04	4	277	07	7	327	16	A'	377	93	.
228	04	4	278	01	1	328	65	×	378	00	0
229	00	0	279	07	7	329	02	2	379	00	0
230	00	0	280	03	3	330	75	-	380	05	5
231	02	2	281	07	7	331	43	RCL	381	01	1
232	04	4	282	69	OP	332	11	11	382	00	0
233	03	3	283	03	03	333	65	×	383	04	4
234	01	1	284	69	OP	334	43	RCL	384	05	5
235	69	OP	285	05	05	335	13	13	385	07	7
236	02	02	286	98	ADV	336	85	+	386	04	4
237	02	2	287	98	ADV	337	43	RCL	387	94	+/-
238	01	1	288	98	ADV	338	04	04	388	85	+
239	01	1	289	25	CLR	339	95	=	389	43	RCL
240	07	7	290	91	R/S	340	55	÷	390	15	15
241	01	1	291	99	PRT	341	43	RCL	391	19	D'
242	07	7	292	42	STO	342	13	13	392	35	1/X
243	03	3	293	02	02	343	19	D'	393	95	=
244	07	7	294	43	RCL	344	35	1/X	394	42	STO
245	69	OP	295	12	12	345	95	=	395	03	03
246	03	03	296	75	-	346	42	STO	396	39	COS
247	05	5	297	91	R/S	347	03	03	397	33	X²
248	07	7	298	99	PRT	348	19	D'	398	55	÷
249	03	3	299	95	=	349	55	÷	399	01	1

400	02	2	450	03	3	500	02	2	550	02	02
401	01	1	451	07	7	501	02	2	551	69	OP
402	93	.	452	02	2	502	02	2	552	05	05
403	06	6	453	04	4	503	04	4	553	17	B'
404	04	4	454	03	3	504	69	OP	554	98	ADV
405	85	+	455	07	7	505	01	01	555	69	OP
406	01	1	456	69	OP	506	03	3	556	00	00
407	95	=	457	01	01	507	07	7	557	01	1
408	16	A'	458	04	4	508	04	4	558	03	3
409	39	COS	459	01	1	509	01	1	559	03	3
410	33	X^2	460	01	1	510	01	1	560	01	1
411	55	÷	461	06	6	511	06	6	561	03	3
412	01	1	462	01	1	512	01	1	562	02	2
413	06	6	463	07	7	513	07	7	563	03	3
414	09	9	464	00	0	514	00	0	564	07	7
415	93	.	465	00	0	515	00	0	565	02	2
416	01	1	466	00	0	516	69	OP	566	03	3
417	05	5	467	00	0	517	02	02	567	69	OP
418	06	6	468	69	OP	518	69	OP	568	01	01
419	07	7	469	02	02	519	05	05	569	01	1
420	85	+	470	69	OP	520	17	B'	570	07	7
421	01	1	471	05	05	521	18	C'	571	03	3
422	95	=	472	17	B'	522	98	ADV	572	05	5
423	16	A'	473	43	RCL	523	42	STO	573	07	7
424	39	COS	474	10	10	524	05	05	574	01	1
425	16	A'	475	65	×	525	69	OP	575	00	0
426	38	SIN	476	89	π	526	00	00	576	00	0
427	55	÷	477	55	÷	527	03	3	577	00	0
428	01	1	478	01	1	528	00	0	578	00	0
429	09	9	479	00	0	529	01	1	579	69	OP
430	06	6	[illegible]	08	8	530	03	3	580	02	02
431	93	.	481	00	0	531	03	3	581	69	OP
432	09	9	482	00	0	532	03	3	582	05	05
433	00	0	483	75	-	533	00	0	583	61	GTO
434	02	2	484	18	C'	534	00	0	584	38	SIN
435	07	7	485	55	÷	535	01	1	585	76	LBL
436	03	3	486	43	RCL	536	03	3	586	16	A'
437	85	+	487	14	14	537	69	OP	587	65	×
438	01	1	488	95	=	538	01	01	588	43	RCL
439	16	A'	489	98	ADV	539	03	3	589	03	03
440	95	=	490	42	STO	540	01	1	590	92	RTN
441	98	ADV	491	05	05	541	02	2	591	76	LBL
442	42	STO	492	69	OP	542	02	2	592	18	C'
443	05	05	493	00	00	543	02	2	593	43	RCL
444	69	OP	494	02	2	544	07	7	594	02	02
445	00	00	495	07	7	545	01	1	595	92	RTN
446	02	2	496	03	3	546	07	7	596	76	LBL
447	07	7	497	02	2	547	00	0	597	19	D'
448	01	1	498	03	3	548	00	0	598	65	×
449	03	3	499	01	1	549	69	OP	599	01	1

600	00	0
601	92	RTN
602	76	LBL
603	15	E
604	99	PRT
605	98	ADV
606	09	9
607	42	STO
608	00	00
609	01	1
610	01	1
611	42	STO
612	01	01
613	76	LBL
614	33	X^2
615	43	RCL
616	00	00
617	98	ADV
618	99	PRT
619	75	-
620	08	8
621	95	=
622	91	R/S
623	99	PRT
624	72	ST*
625	00	00
626	69	OP
627	20	20
628	00	0
629	97	DSZ
630	01	01
631	33	X^2
632	61	GTO
633	38	SIN
634	92	RTN
635	76	LBL
636	17	B'
637	43	RCL
638	05	05
639	65	×
640	01	1
641	08	8
642	00	0
643	55	÷
644	89	π
645	95	=
646	22	INV
647	88	DMS
648	42	STO
649	05	05
650	01	1
651	06	6
652	01	1
653	07	7
654	02	2
655	02	2
656	69	OP
657	04	04
658	43	RCL
659	05	05
660	59	INT
661	22	INV
662	44	SUM
663	05	05
664	69	OP
665	06	06
666	03	3
667	00	0
668	02	2
669	04	4
670	03	3
671	01	1
672	69	OP
673	04	04
674	43	RCL
675	05	05
676	65	×
677	01	1
678	00	0
679	00	0
680	95	=
681	42	STO
682	05	05
683	59	INT
684	22	INV
685	44	SUM
686	05	05
687	69	OP
688	06	06
689	03	3
690	06	6
691	01	1
692	07	7
693	01	1
694	05	5
695	69	OP
696	04	04
697	43	RCL
698	05	05
699	65	×
700	01	1
701	00	0
702	00	0
703	95	=
704	58	FIX
705	05	05
706	69	OP
707	06	06
708	22	INV
709	58	FIX
710	92	RTN
711	76	LBL
712	11	A
713	70	RAD
714	22	INV
715	58	FIX
716	81	RST
717	00	0
718	00	0
719	00	0
720	25	CLR
721	70	RAD
722	98	ADV
723	81	RST
724	76	LBL
725	19	D'
726	88	DMS
727	65	×
728	89	π
729	55	÷
730	01	1
731	08	8
732	00	0
733	54	)
734	92	RTN
735	76	LBL
736	16	A'
737	43	RCL
738	08	08
739	55	÷
740	43	RCL
741	01	01
742	55	÷
743	02	2
744	04	4
745	65	×
746	53	(
747	43	RCL
748	08	08
749	33	X^2
750	55	÷
751	43	RCL
752	01	01
753	75	-
754	01	1
755	02	2
756	65	×
757	43	RCL
758	06	06
759	54	)
760	95	=
761	44	SUM
762	08	08
763	61	GTO
764	88	DMS
765	76	LBL
766	17	B'
767	03	3
768	00	0
769	03	3
770	07	7
771	03	3
772	05	5
773	03	3
774	06	6
775	69	OP
776	04	04
777	92	RTN
778	76	LBL
779	18	C'
780	58	FIX
781	03	03
782	69	OP
783	06	06
784	98	ADV
785	22	INV
786	58	FIX
787	69	OP
788	00	00
789	92	RTN
790	00	0
791	00	0
792	00	0
793	00	0
794	00	0
795	00	0
796	00	0
797	00	0
798	00	0
799	00	0

AD-A118 854 ARMY WAR COLL CARLISLE BARRACKS PA F/G 9/2
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APPENDIX

Lambert Projection Constants*

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	10	3 000 000	7.5707 74528	2 099 382.342	9.19729 71118	30.58736	-106
Alaska*	50.0	10 560	16 564 628.77	0.79692 23940	397.02694	6.40	
	North	2 000 000	13.9445 87488	2 099 566.849	6.18653 07455	55.65314	0.93
Arkansas	3.1	5 520	29 732 882.87	0.58189 91407	394.62757	999	
	South	2 000 000	14.7718 94984	2 099 530.173	5.91651 81558	58.94981	0.88
Arkansas	3.2	5 520	31 511 724.20	0.55969 06871	394.47485	999	
	I	2 000 000	11.5482 67459	2 099 480.129	7.10187 84606	46.10317	1.13
California	4.1	7 320	24 792 436.23	0.65388 43192	395.34551	999	
	II	2 000 000	12.2865 33640	2 099 522.214	6.79664 27326	49.04553	1.06
California	4.2	7 320	26 312 257.65	0.63046 79732	395.10340	999	
	III	2 000 000	12.8872 57544	2 099 552.659	6.56416 00543	51.43955	1.01
California	4.3	7 230	27 512 992.04	0.61223 20427	394.91922	999	
	IV	2 000 000	13.4228 96887	2 099 576.982	6.38804 49092	53.57406	0.97
California	4.4	7 140	28 652 931.96	0.59658 71443	394.76790	999	
	V	2 000 000	14.3813 29439	2 099 537.853	6.04136 52389	57.39339	0.91
California	4.5	7 080	30 649 424.27	0.57001 19219	394.51692	999	
	VI	2 000 000	15.1678 86218	2 099 605.078	5.79450 10359	60.52780	0.86
California	4.6	6 975	32 271 267.72	0.54951 75982	394.33154	999	
	VII	4 186 692.58	14.7124 42842	2 099 677.289	5.93522 87569	58.71246	0.88
California	4.7	7 100	35 055 396.31	0.56124 32071	394.44057	999	
	North	2 000 000	11.7888 03056	2 099 610.755	6.99996 40610	47.06188	1.11
Colorado	5.1	6 330	25 086 068.20	0.64613 34829	395.26427	999	
	Central	2 000 000	12.2793 79233	2 099 566.796	6.79949 49875	49.01733	1.06
Colorado	5.2	6 330	26 243 052.74	0.63068 95773	395.10497	999	

* In eastern hemisphere use L2 = -11040 and enter longitude as negative east of Greenwich.

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Colorado	South 5.3	2 000 000 6 330	12.8487 82891 27 402 231.82	2 099 586.717 0.61337 80528	6.57864 36904 594.93171	51.28621 999	1.01
Connecticut	 6.0	600 000 4 365	11.2680 94062 23 914 389.02	2 099 665.962 0.66305 94147	8.27090 58758 595.44397	44.98648 999	1.16
Florida	North 9.3	2 000 000 5 070	17.1606 79006 36 454 924.53	2 099 593.089 0.50252 59000	5.24307 17084 593.93314	68.46860 999	0.76
Iowa	North 14.1	2 000 000 5 610	10.8292 50755 23 162 461.59	2 099 586.652 0.67774 45518	7.42152 89284 595.60346	43.23744 999	1.21
Iowa	South 14.2	2 000 000 5 610	11.4005 83645 24 374 096.67	2 099 592.955 0.65870 10213	7.16567 22121 595.39708	45.51460 999	1.15
Kansas	North 15.1	2 000 000 5 880	12.2141 49149 25 979 068.57	2 099 610.772 0.63271 48646	6.82539 35033 595.12526	48.74582 999	1.07
Kansas	South 15.2	2 000 000 5 910	12.8102 73201 27 351 521.50	2 099 566.813 0.61452 81068	6.59319 50618 594.94263	51.13276 999	1.02
Kentucky	North 16.1	2 000 000 5 055	12.5602 72222 26 724 051.82	2 099 621.745 0.62206 72671	6.68900 50779 595.01754	50.13644 999	1.04
Kentucky	South 16.2	2 000 000 5 145	13.0825 08590 27 832 235.64	2 099 586.678 0.60646 23718	6.49148 93225 594.86305	52.21782 999	1.00
Louisiana	North 17.1	2 000 000 5 550	16.0153 41985 34 079 629.33	2 099 522.345 0.52870 06734	5.54785 31326 594.15095	63.90452 999	0.81
Louisiana	South 17.2	2 000 000 5 480	17.2758 29558 36 756 553.45	2 099 545.450 0.50001 26971	5.21410 08548 593.91292	68.92709 999	0.75
Louisiana	Offshore 17.3	2 000 000 5 480	19.5723 41939 41 576 762.39	2 099 480.464 0.45400 68519	4.69199 30345 593.56012	80.02091 4.33	1.51

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
		800 000	12.3783 21478	2 099 596.059	6.76022 71189	49.41137	1.05
Maryland	19.0	4 620	26 369 112.76	0.62763 41196	595.07374	999	
	Mainland	600 000	11.0076 57990	2 099 626.929	7.34005 64125	43.94857	1.19
Massachusetts	20.1	4 290	23 549 477.32	0.67172 86561	595.53621	999	
	Island	200 000	11.3276 65409	2 099 698.180	7.19751 84389	45.22407	1.15
Massachusetts	20.2	4 230	23 924 398.02	0.66109 53994	595.42209	999	
	North	2 000 000	9.5455 94618	2 099 577.552	8.05286 43674	38.68598	7.89
Michigan	21.6	5 220	20 589 420.09	0.72278 99381	596.11375	6.20	
	Central	2 000 000	10.0027 30252	2 099 598.279	7.81862 74014	40.56489	6.61
Michigan	21.7	5 060	21 594 768.40	0.70640 74180	595.92424	6.08	
	South	2 000 000	10.7472 84488	2 099 586.043	7.45945 18656	43.62769	4.95
Michigan	21.8	5 060	23 069 597.22	0.68052 92633	595.63317	6.00	
	North	2 000 000	9.0423 16733	2 099 497.306	8.32350 57512	36.11389	1.45
Minnesota	22.1	5 586	19 471 398.75	0.74121 96637	596.33159	999	
	Central	2 000 000	9.5290 88412	2 099 537.632	8.06152 53999	38.05459	1.37
Minnesota	22.2	5 655	20 493 457.15	0.72338 80702	596.12002	999	
	South	2 000 000	10.1579 53472	2 099 537.679	7.74151 09282	40.56153	1.29
Minnesota	22.3	5 640	21 874 349.14	0.70092 77824	595.86162	999	
	North	2 000 000	8.9012 80761	2 099 641.490	8.40183 14127	35.55153	1.47
Montana	25.1	6 570	19 157 874.26	0.74645 18080	596.39431	999	
	Central	2 000 000	9.2558 18806	2 099 537.617	8.20702 13948	36.96514	1.41
Montana	25.2	6 570	19 919 806.36	0.73335 38278	596.23754	999	
	South	2 000 000	9.7644 74280	2 099 514.006	7.93936 49928	38.99298	1.34
Montana	25.3	6 570	21 096 820.93	0.71490 12442	596.02133	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
Nebraska	North 26.1	2 000 000 6 000	10.9563 97056 23 368 977.46	2 099 626.928 0.63735 07906	7.36331 64959 595.55498	43.74423 999	1.19
Nebraska	South 26.2	2 000 000 5 970	11.4808 89640 24 590 781.86	2 099 537.738 0.65607 64003	7.13086 65818 595.36895	45.83467 999	1.14
New York	Long Island 31.4	2 000 000 4 440	11.5421 76825 24 462 545.30	2 099 690.654 0.65408 20950	7.10449 08273 595.34864	46.07893 999	1.13
North Carolina	 32.0	2 000 000 4 740	14.1166 91879 30.183 611.25	2 099 433.757 0.57717 07700	6.12860 74841 594.58393	56.33878 999	0.92
North Dakota	North 33.1	2 000 000 6 030	8.9636 82598 19 215 516.01	2 099 566.651 0.74413 33961	8.36703 98661 596.36765	35.80031 999	1.46
North Dakota	South 33.2	2 000 000 6 030	9.3643 26488 20 086 977.18	2 099 566.671 0.72938 26040	8.14877 03843 596.19052	37.39771 999	1.40
Ohio	North 34.1	2 000 000 4 950	11.4541 06100 24 559 158.47	2 099 573.576 0.65695 03193	7.14244 39257 595.37833	45.72791 999	1.14
Ohio	South 34.2	2 000 000 4 950	12.1562 57795 26 027 071.12	2 099 566.844 0.63451 95439	6.84889 67952 595.14400	48.52639 999	1.07
Oklahoma	North 35.1	2 000 000 5 880	13.6492 91606 29 082 831.70	2 099 586.740 0.59014 70744	6.28815 79862 594.70553	54.47632 999	0.95
Oklahoma	South 35.2	2 000 000 5 880	14.4709 99525 30 838 032.96	2 099 566.862 0.56761 66827	6.01229 51464 594.49510	57.75084 999	0.90
Oregon	North 36.1	2 000 000 7 230	9.9244 81684 21 383 852.48	2 099 480.014 0.70918 60222	7.85796 14005 595.95556	39.63095 999	1.32
Oregon	South 36.2	2 000 000 7 230	10.6413 53445 22 888 667.15	2 099 480.066 0.68414 73833	7.50892 71822 595.67384	42.48847 999	1.23

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3141 69244	2 099 610.741	7.20343 82515	45.15854	1.15
Pennsylvania	37.1	4 665	24 211 050.37	0.66153 97363	595.42678	999	
	South	2 000 000	11.7058 53283	2 099 616.327	7.03483 46103	46.73136	1.11
Pennsylvania	37.2	4 665	24 984 826.43	0.64879 31663	595.29239	999	
	North	2 000 000	14.5886 44817	2 099 586.762	5.97452 58161	58.21947	0.89
South Carolina	39.1	4 860	31 127 724.75	0.56449 73800	594.46706	999	
	South	2 000 000	15.3613 74673	2 099 559.902	5.73648 89600	61.74753	0.84
South Carolina	39.2	4 860	32 676 887.64	0.54465 15700	594.28950	999	
	North	2 000 000	9.9652 16243	2 099 573.515	7.83744 62836	39.79320	1.31
South Dakota	40.1	6 000	21 366 697.03	0.70773 81841	595.93990	999	
	South	2 000 000	10.4755 96174	2 099 505.865	7.58740 89499	41.82781	1.25
South Dakota	40.2	6 020	22 461 937.05	0.68985 19579	595.73842	999	
		2 000 000	13.8170 73482	2 099 593.024	6.23006 34541	55.14496	0.94
Tennessee	41.0	5 160	29 535 149.91	0.58543 97296	594.66031	999	
	North	2 000 000	14.0303 44192	2 099 514.231	6.15754 99858	55.99482	0.93
Texas	42.1	6 090	29 972 959.94	0.57953 58654	594.60575	999	
	N.Central	2 000 000	15.3316 61298	2 099 433.907	5.74533 06210	61.18035	0.85
Texas	42.2	5 850	32 691 654.54	0.54539 44146	594.29572	999	
	Central	2 000 000	16.6003 72791	2 099 453.060	5.38829 78793	66.23589	0.78
Texas	42.3	6 020	35 337 121.23	0.51505 88857	594.03580	999	
	S.Central	2 000 000	17.7485 26687	2 099 414.214	5.09816.44664	70.81092	0.73
Texas	42.4	5 940	37 807 440.38	0.48991 26408	593.83362	999	
	South	2 000 000	19.5723 41939	2 099 480.464	4.69199 30345	78.07853	0.66
Texas	42.5	5 910	41 576 762.39	0.45400 68519	593.56012	999	

	ZONE CODE	L1 L2	L3 L4	L5 L6	L7 L8	L9 L10	L11
	North	2 000 000	11.3806 20205	2 099 610.744	7.17436 79884	45.43514	1.15
Utah	43.1	6 690	24 229 110.29	0.65935 54910	595.40334	999	
	Central	2 000 000	11.9634 71949	2 099 488.916	6.92746 87843	47.75829	1.09
Utah	43.2	6 690	25 664 114.42	0.64057 85926	595.20647	999	
	South	2 000 000	12.8719 59904	2 099 599.094	6.56991 23007	51.37860	1.01
Utah	43.3	6 690	27 432 812.88	0.61268 73424	594.92390	999	
	North	2 000 000	12.4929 92805	2 099 592.988	6.71519 24430	49.86859	1.04
Virginia	45.1	4 710	26 576 444.45	0.62411 78597	595.03784	999	
	South	2 000 000	13.0667 62019	2 099 586.724	6.49729 89409	52.15482	1.00
Virginia	45.2	4 710	27 811 312.71	0.60692 48249	594.86773	999	
	North	2 000 000	8.9532 57623	2 099 580.115	8.37283 68522	35.75876	1.46
Washington	46.1	7 250	19 205 863.43	0.74452 03390	596.37236	999	
	South	2 000 000	9.4462 70779	2 099 522.021	8.01519 85672	37.72440	1.39
Washington	46.2	7 230	20 289 119.60	0.72639 57947	596.15605	999	
	North	2 000 000	12.0524 41881	2 099 576.946	6.89102 19040	48.11250	1.08
West Virginia	47.1	4 770	25 715 126.55	0.63777 29696	595.17836	999	
	South	2 000 000	12.6881 39167	2 099 545.339	6.63970 86618	50.64632	1.03
West Virginia	47.2	4 860	27 070 620.78	0.61819 53936	594.97852	999	
	North	2 000 000	9.5848 07314	2 099 586.605	8.03234 65428	38.27671	1.36
Wisconsin	48.1	5 400	20 489 179.67	0.72137 07913	596.09808	999	
	Central	2 000 000	10.0261 85452	2 099 576.862	7.80689 71899	40.03631	1.30
Wisconsin	48.2	5 400	21 430 913.91	0.70557 66312	595.91485	999	
	South	2 000 000	10.5552 75906	2 099 559.732	7.54951 94619	42.14537	1.24
Wisconsin	48.3	5 400	22 672 134.66	0.68710 32423	595.70670	999	

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