

TRGLEV

TRIGONOMETRICAL LEVELLING NETWORK ADJUSTMENT

USER DOCUMENTATION

Version 2.6.3

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DEPARTMENT OF FINANCE AND SERVICES**

BATHURST

April 2014

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1. INTRODUCTION

This documentation has been written to provide a description of the program TRGLEV developed for the Department of Lands and programmed in the Fortran 77 language. The version of the program described in this documentation is TRGLEV 2.6. It runs on various HP computers using the HP-UX operating system and also runs on IBM compatible PCs with the name TRGLEV MS-2.6. There are also NT and Linux versions called TRGLEV G77-2.6.

The documentation contains descriptions of the functions provided by the program for the Department of Lands. Some of these functions are not applicable to the PC version because they require access to internal geodetic data bases.

1.1 Development History

The development of a trigonometrical height adjustment program was first proposed in February 1978.

At that time the processing of zenith distance observations to obtain heights of geodetic stations was carried out using the program LEVADJ. This was a cumbersome and time consuming process because height differences and reduction to centre computations were required before LEVADJ, a program designed for spirit levelling adjustments, could be used.

The coefficient of refraction could be determined only for simultaneous reciprocal observations and had to be assumed for one way observations. Weighting of observations in terms of standard deviations of observed values was not possible.

It was proposed that a combination of the parametric method and condition method be used to form observation equations. After investigation of the proposal it was decided that systems development could be more easily accomplished if the coefficient of refraction was regarded as an observation with an appropriate weight. In this case an equation of one unknown is included for each refraction parameter in the adjustment.

Programs were developed for testing the feasibility of the method in 1979 and testing was commenced. By early 1980 it was apparent that the method was able to produce results very close to those obtained from current methods while using a more rigorous mathematical approach. Input was simplified and made more flexible by directly entering observed values and output was easy to interpret.

Other advantages were that precision analysis could be achieved by inverting the normal matrix and reduction to centre could be computed using eccentric mark data stored on file.

Program development was begun in 1980 and testing of the program was carried out during 1981 and 1982. The program was put into production early in 1983.

In November 1987 the program was converted to run on a VAX 11/750. For this conversion, a Fortran 77 compiler was used requiring some changes to the code. The input and output subroutines which were originally coded in PDP Assembler language were also converted to Fortran 77.

As part of the conversion the program was enhanced in some areas to improve the detection of data errors and to increase the capacity.

In 1991 the program was transferred to a HP-9000 minicomputer and modified to run using the HP-UX operating system. It was also installed on an IBM compatible PC using the Microsoft compiler.

In June 1994 version 2.0 was created. This resulted from modifications to enable the program to compute provisional heights to be used for the adjustment and also for the processing of three dimensional coordinate differences. This version also includes a model to be used for determining the geoid-ellipsoid separation.

1.2 Development Status

TRGLEV Version 2.6 has been well tested and the results have been compared with other programs. The PC version is being used by Land and Property Information and also by other government and private organisations.

In December 2007 it was compiled using the G77 compiler to create a 32 bit executable. This also runs on Windows XP and Windows 7. A Linux version is also used internally.

In August 2009 a version for larger networks was created. This is called TRGLEVL. The capacity was increased from 1000 stations to 2000.

1.3 Functions of the Program

The program performs the following functions for the geodetic and survey control activities of Land and Property Information.

- The computation of heights from field observations using vertical angle and height difference observations and also three dimensional cartesian coordinate differences.
- The height adjustment of networks by the parametric method (variation of heights) using local coordinates, AMG and ISG grid coordinates based on the Australian National Spheroid, UTM grid coordinates based on WGS72 and MGA94 grid coordinates on the GDA94 datum. It can also be run using the entry of distances with height observations. In this case coordinate values for stations are not required.
- A statistical analysis of adjustment results using the standard deviations of adjusted heights and residual analysis output.
- The analysis of networks of height adjustment observations for the purpose of optimization.
- The creation of adjusted height and observation files for the plotting of network diagrams and for updating information in geodetic data bases.

1.4 Standard Fortran Version

In November 1989 the program code was converted to standard Fortran to run on HP minicomputers using the Unix operating system. The conversion to standard code has allowed compilation of the program using the Microsoft Fortran compiler, the Lahey compiler and the G77 compiler for IBM compatible personal computers and for Linux minicomputers.

1.5 Operation of the Program

TRGLEV reads data for an adjustment from a text file formatted according to the specification given in Section 4. All adjustment options are contained in the input file.

To run the program the word 'trglev' should be entered at the Unix or Command prompt window. The names of the input file and output file can also be entered on the command line. If the input file name alone is entered, the program derives the output file name from the input file name by appending the extension ".prt". This indicates that it is a file for printing or viewing.

If an existing output file is found the program displays a message and waits for a response by the user to indicate whether it should be overwritten or not. The default response is 'y'.

If the first command line argument is '-o' the existing output file message is not displayed and the new output file will overwrite an existing file.

1.6 Relationship with HAVOC Program

TRGLEV was designed to be used for network adjustments in conjunction with the horizontal adjustment program, HAVOC. Because of this, the data record types are compatible with HAVOC. The station record is the same and observation records are similar with unique record identifiers being used for horizontal and vertical observations.

The output of both programs contains similar information so that a user familiar with one program should easily be able to interpret the output of the other.

For the solution and inversion of the normal matrix, HAVOC and TRGLEV use the same algorithms and subroutines.

It can be run with HAVOC iteratively for a three dimensional adjustment of a network of horizontal and vertical observations. A program called HAVLEV is available for this.

2. FUNCTIONS OF TRGLEV

2.1 Introduction

TRGLEV was designed to determine the heights of geodetic stations by the least squares adjustment of networks comprising zenith distance and height difference observations using the parametric method. The parameters used are corrections to provisional heights, corrections to provisional coefficient of refraction values and corrections to provisional rotational parameters.

2.2 Types of Observation Accepted

A variety of observation types can be processed by TRGLEV to obtain a least squares solution for the parameters used in the adjustment. These parameters are corrections to provisional heights, corrections to provisional values for the coefficient of refraction and corrections to provisional values of auxiliary parameters if required.

The types of observations that can be accepted by the program are described below.

2.2.1 Zenith Distance

A zenith distance between two stations can be entered. This type of observation also requires the distance between the two stations. This can either be entered with the zenith distance or computed from station coordinates if they have been supplied with the station data. To compute the ellipsoidal radius for long lines the azimuth of the line is also required. As with distances this will be computed from coordinates if available.

An option for the entry of vertical angle data is also available if required. This type of data will be immediately converted to zenith distances by the program.

Distances needed for the computation are ellipsoidal distances. Spatial distances will be reduced to sea level distances by the program and if the option is selected in the option record, sea level distances will be reduced to ellipsoidal distances.

2.2.2 Coefficient of Refraction

An observed value for the coefficient of refraction can be entered with the zenith distance observation. This will be used as the provisional value for the associated zenith distance observation.

2.2.3 Height Difference

A height difference observation can be entered between any two stations.

2.2.4 Height

An observation equivalent to a position equation in a horizontal adjustment can be entered for height. This is done by entering a standard deviation for the height with the station data. This type of observation provides a constraint on the change of a station height without fixing it.

The adjustment is usually done using orthometric heights. If ellipsoidal heights are entered they are converted to orthometric heights using a geoid-ellipsoid separation model for NSW stored within the program. Models for both ANS and GRS80 ellipsoids are available. The accuracy of this model is limited and currently provides the separation to the nearest 0.3 metre.

2.2.5 Three Dimensional Cartesian Coordinate Differences

Cartesian coordinate differences derived from GPS data capture can be entered as observations. Although the program is not intended for the adjustment of this type of data, it can be used to provide height difference information for the adjustment. The observations are converted to height differences for the adjustment.

2.2.6 Auxiliary Parameters

Auxiliary parameters representing rotation corrections about the easting and northing coordinate axes can be introduced into the adjustment. These can be used when entering height differences derived from a different datum to that defined by the fixed stations.

This facility was included to allow the use of height differences derived from WGS84 cartesian coordinate differences.

2.3 Processing Options

Processing is carried out in four stages.

1. Stage one includes the reading and editing of input data, computing provisional heights, the re-arrangement of the order of station input to obtain a minimum bandwidth for the normal matrix and the formation of observation equations.
2. Stage two includes the formation and solution of normal equations, the computation of adjusted heights and coefficients of refraction, auxiliary parameters, residuals and precision analysis.
3. Stage three includes the printing of a list of adjusted stations showing heights and standard deviations and a separate list of fixed stations.
4. Stage four jobs produce a disc file of station information including coordinates and heights for producing a diagram and updating the Geodetic Control Register.

Processing can be stopped after stage one if required. This option can be used for checking observation data for gross errors before considerable computer time is used forming and solving the normal equations.

2.4 Mathematical Method

The method used for the adjustment is the parametric method of least squares. Provisional heights are entered for each station in the network. For each observation entered the observed value is subtracted from the value computed from the provisional heights. This difference is the absolute term of the observation equation.

The zenith distance observation equations computed by the program express the relationship between a small change in zenith distance and small changes in station heights and coefficients of refraction. The latter values are the parameters to be computed in the adjustment.

Height difference observation equations similarly express the relationship between a small change in height difference and small changes in station heights. An observation equation is computed for each observation entered and for each coefficient of refraction used.

The former equations have two or three unknowns and the latter only one unknown. Equations representing observed heights also with one unknown can be included.

For each observation equation used, suitable weights are entered in the form of a standard deviation of the observed quantity.

The main advantage of this method is that the values obtained for the parameters after the solution of the normal equations are the corrections to be applied to the provisional values.

The heights and coefficients of refraction obtained in the adjustment are those which satisfy the least squares requirement that the sum of the weighted squares of the residuals be minimised.

2.5 Computation of Provisional Heights

The program will automatically use the observations supplied to compute provisional heights for stations entered. The observations used for this computation are the zenith distances, height differences and cartesian coordinate differences.

When a station without a height is detected the program searches through all observations to find a connection to a station with a height available. For the first attempt it will use only height difference observations because these are not dependent on station coordinates. This is preferable when the program is being used in three dimensional adjustment mode.

If a height cannot be determined from height difference observations, it uses zenith distance observations or cartesian coordinate differences if available.

An iterative process is used for computation in which a count of the number of stations for which height is computed during each iteration is maintained. If after two consecutive iterations, no heights have been determined the process is stopped.

2.6 Reduction to Centre

Observations can be reduced to centre before being used in the adjustment. The data required for this are the height of instrument, height of target, height difference between occupied eccentric and main station and height difference between observed eccentric and main station.

For eccentric stations the height differences needed can be automatically read from the disk file of eccentric data for geodetic stations maintained by the Department of Lands. To use this facility the identification numbers of the eccentrics used in the observation must be entered with other observation data.

When the eccentric file is used, the observed zenith distance is also corrected to allow for the difference between the eccentric distance and the mark to mark distance. If an observed distance between eccentric marks is entered this is also reduced to centre.

2.7 Automatic Minimising of Bandwidth

The normal equations are solved by the Cholesky method. This method is very suitable for solving a matrix which has coefficients grouped in a band about the main diagonal. It is possible to save significant amounts of computer time during the solution if this band is kept as narrow as possible.

The bandwidth is minimised by the program by re-arranging the order and therefore the sequence numbers of stations so that the differences between sequence numbers of connected stations are minimised.

2.8 Estimation of Precision of Adjusted Heights

If required the normal matrix can be inverted and the elements obtained can be used for precision estimation of the adjusted heights and also relative heights. This is analogous to the use of error ellipses in a horizontal adjustment for the analysis of two dimensional precision. Height precision analysis is the one dimensional case and therefore much simpler in concept.

The inversion of the normal matrix can require extensive computer time for a large matrix so this facility has been made optional.

2.9 Reiteration of Adjustment

The adjustment can be reiterated if required although for this type of adjustment it is rarely necessary. Adjusted station heights from the previous iteration are used as provisional heights for the current iteration.

Observed heights and refraction coefficients are used as entered in subsequent iterations because they are observations and not parameters. The corrections to these values obtained from the adjustment are equivalent to residuals.

If distances are entered as spatial values, the reduction to the ellipsoid is dependent on the heights of the stations. In this case a small change in the reduced distance will occur when the heights change and reiteration could be necessary for convergence.

2.10 Station Information from External Files

When the station label format is being used, the program will search for station data in a text files using the label as the station identifier. If required, the program can be run with an input file containing observation data only. The file must have the format of TRGLEV station data and be named 'station.dat' or have a name based on the input file name with the extension '.stn'.

2.11 Automatic Omission of Stations

If observations to an unfixed station have been omitted from the input data, a zero term will occur on the diagonal of the normal matrix. This would cause the solution to fail. To prevent this happening, the program checks that every station in the adjustment appears in at least one observation.

This check is done before the formation of the normal equations. Stations that do not fulfill this requirement are excluded from the adjustment by the program and indicated as omitted in the station output.

A station is also excluded if the program is unable to calculate provisional coordinates for it. This exclusion will cause errors related to missing stations to occur during observation processing but will enable errors due to other causes to be detected.

A third reason for the exclusion of a station is the duplication of the number or label allocated to the station. The program uses its own internal sequential number for each station in the adjustment. The duplication of a number will result in the failure to link an observation to the station with the duplicated number. A zero diagonal term in the normal matrix would occur in this situation.

2.12 Automatic Insertion of Stations

The program will automatically include in the adjustment any station shown in an observation but not found in the list of stations. If required this can be used for all stations so that only fixed stations need be entered in the station data section of the input. A station record would be required if a station height or coordinates need to be entered.

When a station is inserted by the program, it places the number of the station in the name field after the word 'Station' and automatically computes the height.

2.13 Check for Duplicated Station Labels

When the label format is used for station coordinate input, the program compares the label entered with the list of labels used for stations previously entered. If a label is found to have been already used the status of the coordinates is checked.

If stations with duplicated labels are indicated as unfixed in the adjustment, second and subsequent stations with the same label are ignored.

If stations with duplicated labels have a status different from the initial station a warning is shown in the station list. For example if the second occurrence of a station label is indicated as fixed when the first is indicated unfixed, a warning is shown in the station list and the second station is omitted from the adjustment.

If stations with duplicated labels are all indicated as fixed, the height values are compared with the initial station and a warning is shown in the station list if they are different.

2.14 Geoid-Ellipsoid Separation Models

The program has stored within it two models representing the separation between the geoid and both the Australian National Spheroid and the GRS80 ellipsoid. These can be used to obtain the separation, N, for any station in the adjustment depending on the ellipsoid used. The value is obtained using the station coordinates.

If the option for reduction of distances to the ellipsoid is selected, the separation value is printed with the station information.

The models currently apply only to the polygon defined by the boundaries of New South Wales and have been obtained from the following sources. The ANS values are from those published in the Australian Geodetic Datum Technical Manual by the National Mapping Council of Australia in 1986.

The GRS80 model is based on the AUSGEOID09 values provided by Geoscience Australia in March 2011. A half degree grid is used in TRGLEV to model the separation so differences of up to 30 centimetres from the full AUSGEOID09 model may be obtained. If better separation values are required, they can be entered in a geoid file described in Section 4.1.4.2 or entered in a station geographical coordinate record shown in Section 4.1.3.2.

3. THEORY AND FORMULAE

3.1 Introduction

For the computation of a least squares adjustment by the method of parameters, observation equations must be developed. These relate the parameters used to differences between observed values and values computed from provisional data. The program computes coefficients for an observation equation for each observation used in the adjustment.

After all observation equations have been completed, normal equations are formed from these and solved to obtain values for the parameters used. The parameters used in this program are corrections to provisional heights, corrections to provisional coefficients of refraction and corrections to auxiliary parameters. These corrections are then applied to the provisional values to obtain adjusted values.

3.2 Observation Equations

Let	H_1	be the provisional height of occupied station (1)
	H_2	be the provisional height of observed station (2)
	S	be the spheroidal distance from '1' to '2'
	Z^o	be the observed zenith distance from '1' to '2'
	Z^c	be the computed zenith distance from '1' to '2'
	D	be the observed height difference from '1' to '2'
	K_1	be the coefficient of refraction at '1'
	θ	be the angle subtended at the centre of the sphere defined by the verticals at '1' and '2' for the mean latitude and azimuth of the line '1-2' ($\theta = S/R$)
	R	be the mean radius of curvature of the circular arc joining '1' and '2' projected on to the spheroid.
	V_Z	be the zenith distance residual after adjustment
	V_K	be the coefficient of refraction residual after adjustment
	V_H	be the height residual after adjustment
	V_D	be the height difference residual after adjustment
	ΔH_1	be the correction to the height of station '1'

ΔH_2 be the correction to the height of station '2'

ΔK be the correction of the coefficient of refraction

$$\text{Let } S' = S \left(1 + \frac{H_1 + H_2}{2R} + \frac{S^2}{12R^2} \right)$$

$$Z' = Z - \theta/2 + K\theta$$

The program processes four types of observation. The observation equations used for each of these are as follows.

3.2.1 Zenith Distance

$$V_Z = \frac{\sin^2 Z'}{S'} \Delta H_1 - \frac{\sin^2 Z'}{S'} \Delta H_2 - \theta \Delta k + Z^c - Z^o$$

3.2.2 Coefficient of refraction

$$V_K = \Delta K$$

3.2.3 Height Difference

$$V_D = \Delta H_1 - \Delta H_2 + (H_1 - H_2) - D$$

3.2.4 Height

$$V_H = \Delta H$$

3.3 Formation and Solution of Normal Equations

The computation for this phase of the adjustment is done using the same algorithms and program code as the program HAVOC. The mathematical techniques used are described in the HAVOC documentation.

4. INPUT AND OUTPUT

4.1 Data Input

The input for the program may contain the following data:

- . Job header.
- . Control options.
- . Provisional and fixed heights.
- . Observed heights.
- . Observed zenith distances.
- . Observed height differences.
- . Observed coefficients of refraction.
- . Heights of stations, instruments, targets, eccentric standpoints and eccentric sightpoints.

4.1.1 Method of Input

Input to the program was originally by punched cards. Input is now by means of a text file. The older format of this file is the same as the format of the cards that were read by the original program.

Two formats of input file are available. In the older format a number is used for the station identifier. The station number is used in the station and observation records to link the observations with the stations.

Another format, in which a character string of up to 12 characters can be used as the station identifier, was developed in 1996. When this format is used, station and observation records must include station labels.

A record type is used to identify each record of the input file. For the station number format this is indicated using the first two columns of the record. For the station label format the first three columns are used.

The first record must be a '92' record, if this type of record is required. For the station number format subsequent records must be entered in ascending numerical order. If the first two columns of the record are blank, or contain characters not recognized by the program, the record is ignored.

The only exception to the ordering of records is the '95' record which can be interspersed with records of all types. The program checks the order of records as they are read. If a record is out of order an error message is printed and the record is ignored.

When the station label format is used, records after the '92' and the '01' records can be entered in any order. The program sorts them as they are read.

A correctly formatted file can be created using a general purpose text editing program. Alternatively a program specifically designed for data entry could be used to enter data.

4.1.2 Station Number Format

4.1.2.1 Adjustment Description Record (92)

Column 1-2 Record type = 92

Column 3-70 Job description of up to 68 characters.

There may be either 1 or 2 of these records if a heading is required, and they must be the first records in the file.

4.1.2.2 Comment Record (95)

Column 1-2 Record Type = 95

Column 3-80 Text

A record of this type is ignored by the program so therefore can be used to insert comments in the data if required. To temporarily remove a record of any type from the adjustment, the record type can be changed to '95' instead of deleting the entire record. The same result can be achieved by changing the first two columns to blanks.

4.1.2.3 Option Record (01)

Column 1-2 Record Type = 01

Column 4-6 Zone number of the grid used for the adjustment. For MGA zones a prefix is included to identify the ellipsoid.

For later versions of the program the zone is assumed to be MGA. To select an AMG zone the prefix '6' or '0' can be used.

The value must be in the range

10-60 for MGA/GDA94
542-562 for ISG
647-658 for AMG/AGD66
701-760 for WGS72
801-860 for MGA/GDA94

These columns should be left blank for an adjustment on a local grid.

Column 8	Refraction option. The options available and the value used to select each one are as follows:										
	<table border="0"> <tr> <td>No.</td> <td>Number of refraction parameters</td> </tr> <tr> <td>0</td> <td>One for the entire network</td> </tr> <tr> <td>1</td> <td>One for each station</td> </tr> <tr> <td>2</td> <td>One for each set of zenith distance observations</td> </tr> <tr> <td>3</td> <td>One for each zenith distance observation</td> </tr> </table>	No.	Number of refraction parameters	0	One for the entire network	1	One for each station	2	One for each set of zenith distance observations	3	One for each zenith distance observation
No.	Number of refraction parameters										
0	One for the entire network										
1	One for each station										
2	One for each set of zenith distance observations										
3	One for each zenith distance observation										
Column 12-15	Computed minus observed limit for zenith distance observations. Default value is 600 seconds of arc.										
Column 16-18	Computed minus observed limit for height observations. Default value is 10 metres.										
Column 20-23	Vertical adjustment number. Necessary only when a file for updating the Geodetic Control Register is to be produced.										
Column 25-26	Vertical adjustment category. For Geodetic Control Register use only.										
Column 28-30	A value which is used to modify the standard deviations of height difference observations in proportion to the distance between the stations. It is entered as parts per million.										
Column 32	A numerical character can be entered to obtain observation equation output.										
Column 34	A numerical character can be entered to obtain the normal equation solution output.										
Column 36	<p>The character '1' can be entered to request that orthometric heights be converted to ellipsoidal heights for distance reduction and for cartesian coordinate difference computations.</p> <p>The character '2' can be entered to indicate that all height values entered are ellipsoidal. In this case the geoid-ellipsoid separation will not be applied.</p>										
Column 38-42	Provisional refraction coefficient value. Default value is 0.065.										
Column 44-48	Refraction coefficient standard deviation. Default value is 0.010.										
Column 51-52	Mean latitude. Required for calculating radius of curvature if coordinates have not been entered. Not necessary for adjustments using local coordinate systems.										
Column 54	Stage of processing required.										

	Enter	1	For data checking phase.
		2	For adjustment followed by computation of heights and height precision.
		3	For the above plus a list of adjusted and fixed stations.
		4	For an output file of adjusted values.
Column 56			The character '1' can be entered to obtain a file of station information after adjustment. This file has the extension '.stn' and has the same format as the station records used as input for the horizontal adjustment program HAVOC as well as TRGLEV.
Column 58			Number of iterations of adjustment phase. Default value is 1.
Column 60-62			Multiplication factor for all zenith distance standard deviations.
Column 64			Precision analysis processing required.
		1	For precision analysis after adjustment.
		2	For relative precision analysis after adjustment.
		3	For precision analysis with normal and inverse matrix printed.
		4	For optimisation.
		5	For optimisation with normal and inverse matrix printed.
Column 66			A numerical character can be entered to use the computed variance factor for precision analysis (default variance factor is 1.0)
Column 68-71			Instrument and target height standard deviation in centimetres. This value represents the combined height standard deviation for both ends of the line. It is applied to the standard deviation of all zenith distance observations.
Column 74			A numerical character can be entered to request the inclusion of rotation parameters in the adjustment. If the number '1' is entered rotation parameters will be included only for height differences derived from three dimensional cartesian coordinate differences. If the number '2' is entered rotation parameters will be included in all height difference observation equations.
Column 76			A numerical character can be entered to request a file of zenith distances derived from cartesian coordinate differences. This file is called 'zenith.dat'.
Column 78			A numerical character can be entered to request the conversion of vertical angle input to zenith distances.
Column 80			A numerical character can be entered to allow the entry of double the usual 'k' factor in the observation records. This convention is used in some systems.

4.1.2.4 Station Record (10)

Column 1-2	Record type = 10
Column 4-6	Station number
Column 7	Station status. Blank for provisional height. Enter the character '-' or '*' to indicate a fixed height.
Column 8-17	Easting coordinate (Optional)
Column 19-29	Northing coordinate (must be entered if easting is entered).
Column 31-50	Station name - up to 20 characters.
Column 52-56	Geodetic control register number.
Column 58	Ellipsoid height indicator. The letter 'E' can be entered to indicate that the station height is entered as an ellipsoidal value.
Column 59-66	Station height. If blank the height will be computed by the program.
Column 67	Station status. This can be used instead of Column 7.
Column 69-73	Standard deviation of height in metres. (Optional. See Section 2.2.4).

4.1.2.5 Station Record (11)

Column 1-2	Record type = 11
Column 4-6	Station number for adjustment.
Column 7	Station status (as in '10' record).
Column 8-10	Station latitude - degrees.
Column 11-12	Station latitude - minutes.
Column 13-20	Station latitude - seconds.
Column 21	Longitude sign.
Column 22-24	Station longitude - degrees.
Column 25-26	Station longitude - minutes.
Column 27-34	Station longitude - seconds.

Column 36-55	Station name - up to 20 characters.
Column 58	Ellipsoid height indicator. The character 'E' can be entered to indicate that the station height is an ellipsoidal value.
Column 59-66	Station height.
Column 67	Station status. (As in '10' record).
Column 69-73	Standard deviation of height in metres. (Optional. See Section 2.2.4).

4.1.2.6 Zenith Distance Record (23)

Column 1-2	Record type = 23
Column 3	Option for simultaneous observation. Enter 'S' for simultaneous observation, otherwise leave blank. To be entered with the second observation of the pair.
Column 4-7	Occupied station number.
Column 9-11	Observed station number.
Column 12	The character 'V' can be entered to indicate that the value entered is a vertical angle. This is converted to a zenith distance.
Column 14-15	Observed zenith distance - degrees.
Column 16-17	Observed zenith distance - minutes.
Column 18-21	Observed zenith distance - seconds.
Column 23-28	Standard deviation of zenith distance in seconds. The default value is 10 seconds.
Column 30-38	Distance. The value required is the ellipsoidal distance. If a different type of distance is entered it will be reduced to the ellipsoid if sufficient information is available. If the distance is not entered it will be computed from coordinates.
Column 39	Type of distance entered '' Sea level distance 'S' Spatial distance 'H' Horizontal distance at height of occupied station 'E' Ellipsoidal distance

Column 40-42	Azimuth. This value is used for the computation of ellipsoidal radius. It is computed from coordinates if available. It is not necessary for short lines.
Column 44-48	Provisional refraction coefficient.
Column 50-54	Height of instrument (If observed from same as preceding station, value may be left blank).
Column 56-61	Height of target.
Column 63-68	Height difference of eccentric standpoint.
Column 70-75	Height difference of eccentric sightpoint.
Column 78	Standpoint eccentric number.
Column 80	Sightpoint eccentric number.

4.1.2.7 Height Difference Record (24)

Column 1-2	Record type = 24
Column 4-7	Occupied station number.
Column 9-11	Observed station number.
Column 13-21	Observed height difference.
Column 23-28	Standard deviation of height difference in metres. The default value is 0.1 metres.
Column 30-38	Distance (Optional).
Column 50-54	Height of instrument.
Column 56-61	Height of target.
Column 78	Standpoint eccentric number.
Column 80	Sightpoint eccentric number.

4.1.2.8 Cartesian Coordinate Difference Record (26)

Column 1-2	Record type = 26
Column 4-7	Number of 'from' station.

Column 9-11	Number of 'to' station.
Column 13-22	X coordinate difference.
Column 24-33	Y coordinate difference.
Column 35-44	Z coordinate difference.
Column 61-64	Standard deviation of derived height difference in metres or derived zenith distance in seconds.
Column 66-70	Height of instrument at 'from' station.
Column 72-76	Height of instrument at 'to' station.
Column 78	Eccentric mark used at 'from' station.
Column 80	Eccentric mark used at 'to' station.

4.1.2.9 End of Data Record (99)

Column 1-2 Record type = 99

This record is not essential.

4.1.3 Station Label Format

An input format in which a 12 character station label can be used as the station identifier is available. This label is shown in both station and observation records instead of the number used for the station identifier in the older format. The program automatically detects the format used for the data.

The '92' and '01' records are the same for both formats.

When this format is used observation and station record types can be mixed so that distance records can be located adjacent to relevant direction or azimuth records if required.

Records entered using this format can include comments preceded by the character '!'. Any text following this symbol is ignored.

4.1.3.1 Station Record (Grid Coordinates)

Column 1-3 Record Type = 'grd' or 'stn'

Column 4	Station status. Blank for an unfixed station. '-' or '*' for a fixed station.
Column 5-16	Station label.
Column 18-37	Station name.
Column 38-48	Easting coordinate.
Column 49-59	Northing coordinate.
Column 60	The letter 'E' can be entered to indicate that the station height entered is an ellipsoidal value.
Column 61-68	Station height in metres. If blank the height will be computed by the program.
Column 69	Station status. This can be used instead of Column 4.
Column 70-74	Standard deviation for height in metres. (Optional. See Section 2.2.4)

4.1.3.2 Station Record (Geographical Coordinates)

Coordinates entered using this record are converted to grid coordinates before being used.

Column 1-3	Record type = 'geo'
Column 4	Station status (as in 'grd' records).
Column 5-16	Station label.
Column 18-37	Station name.
Column 38	Latitude sign. '-' or 'S' for southern latitudes.
Column 39-40	Station latitude - degrees.
Column 42-43	Station latitude - minutes.
Column 45-52	Station latitude - seconds.
Column 53	Longitude sign. '-' or 'W' for western longitudes.
Column 54-56	Station longitude - degrees.
Column 58-59	Station longitude - minutes.

Column 61-68	Station longitude - seconds.
Column 70	The letter 'E' can be entered to indicate that the station height entered is an ellipsoidal value.
Column 71-78	Station height in metres. If blank the height will be computed by the program.
Column 79	Station status. This can be used instead of Column 4.
Column 93-97	Standard deviation of height in metres.
Column 99-105	Geoid-ellipsoid separation in metres.

4.1.3.3 Zenith Distance Record

Column 1-3	Record type = 'zen'
Column 4	Option for simultaneous observation. Enter 'S' for simultaneous observation, otherwise leave blank. To be entered with the second observation of the pair.
Column 5-16	Occupied station label .
Column 19-30	Observed station label.
Column 32-34	Observed zenith distance - degrees.
Column 35-36	Observed zenith distance - minutes.
Column 37-40	Observed zenith distance - seconds.
Column 42-47	Standard deviation of zenith distance in seconds. The default value is 10 seconds.
Column 49-57	Distance. The value required is the ellipsoidal distance. If a different type of distance is entered it will be reduced to the ellipsoid if sufficient information is available. If the distance is not entered it will be computed from coordinates.
Column 58	Type of distance entered. '' Sea level distance 'S' Spatial distance 'H' Horizontal distance at height of occupied station 'E' Ellipsoidal distance

Column 59-61	Azimuth. This value is used for the computation of ellipsoidal radius. It is computed from coordinates if available. It is not necessary for short lines.
Column 63-67	Provisional refraction coefficient.
Column 69-73	Height of instrument (If same as preceding station, value may be left blank).
Column 75-79	Height of target.
Column 81-86	Height difference of eccentric standpoint.
Column 88-93	Height difference of eccentric sightpoint.
Column 95	Standpoint eccentric number.
Column 97	Sightpoint eccentric number.

4.1.3.4 Vertical Angle Record

Column 1-3 Record type = 'ver'

The format of this record is the same as for the zenith distance record described above. The value entered is converted to a zenith distance before processing.

4.1.3.5 Zenith Distance or Vertical Angle without Distance

If station coordinates are entered so that the entry of distances is not required, a different format can be used to enter vertical angle data.

Column 1-3	Record type = 'zen' or 'ver'
Column 4	Option for simultaneous observation. Enter 'S' for simultaneous observation, otherwise leave blank. To be entered with the second observation of the pair.
Column 5-16	Occupied station label .
Column 19-30	Observed station label.
Column 33-35	Observed zenith distance - degrees.
Column 37-38	Observed zenith distance - minutes.
Column 40-43	Observed zenith distance - seconds.

Column 45-50	Standard deviation of zenith distance in seconds. The default value is 10 seconds.
Column 59-63	Provisional refraction coefficient.
Column 66-70	Height of instrument (If same as preceding station, value may be left blank).
Column 74-78	Height of target.
Column 81-86	Height difference of eccentric standpoint.
Column 88-93	Height difference of eccentric sightpoint.
Column 95	Standpoint eccentric number.
Column 97	Sightpoint eccentric number.

4.1.3.6 Height Difference Record

Column 1-3	Record type = 'dif'
Column 5-16	Occupied station label.
Column 19-30	Observed station label.
Column 33-41	Observed height difference.
Column 43-48	Standard deviation of height difference in metres. The default value is 0.1 metres.
Column 54-62	Distance (Optional). Used only for computing weight relative to distance and for output of observation class.
Column 50	Standpoint eccentric number.
Column 52	Sightpoint eccentric number.
Column 69-73	Height of instrument.
Column 75-79	Height of target.

4.1.3.7 Cartesian Coordinate Difference Record

Column 1-3	Record type = 'ccd'
Column 5-16	Label of 'from' station.

Column 19-30	Label of 'to' station.
Column 32-42	X coordinate difference.
Column 43-53	Y coordinate difference.
Column 54-64	Z coordinate difference.
Column 81-84	Standard deviation of derived height difference in metres.
Column 88-92	Height of instrument at 'from' station.
Column 94-98	Height of instrument at 'to' station.
Column 100	Eccentric mark used at 'from' station.
Column 102	Eccentric mark used at 'to' station.

4.1.4 Other Input Files

The program checks for the existence of several types of file which may contain data to be used for the adjustment process. If any of the files are not found it is assumed that the supply of this type of data is not required.

4.1.4.1 Option File

The program reads a file called TRGLEV.OPT which can be used to specify default options and disk drives and paths to be used for file storage. If the file does not exist, the program continues running with files opened in the program directory and the options that have been selected in the option record.

There are three types of file which can be assigned to a disk drive and path. These are the input, output and work files.

As TRGLEV.OPT is read, the file type is recognised by the first four characters of the line. Because of this, lines in the file can appear in any order. Any line not matching a file type or an option record is ignored.

The drive letters recognised by the program are the letters 'A' to 'Z' and 'a' to 'z' except for the characters 'x' and 'X' which are ignored. The path must be preceded by the character '=' and no blanks are allowed within the path string.

The program runs much faster if the work files are assigned to the RAMDRIVE which is the usual way of utilising extended memory.

If an option record ('01') is found in this file, options selected in this record are added to the option record entered with the adjustment data. If required the entire option record can be held in the file TRGLEV.OPT so that it is not necessary to include one with the input data.

Option selection characters are transferred from the file only if the corresponding character in the option record with the adjustment data is blank. Therefore options selected with the input data have precedence.

An example of an option file is shown in Appendix A.

4.1.4.2 Geoid File

A file can be used to enter geoid values if required. This is accessed using the station label and so can be used only with the label format. The file must be named 'geoid.dat'.

The record structure is as follows.

Column 1-12	Station label
Column 14-20	Geoid-ellipsoid separation
Column 22-27	Vertical deflection in meridian
Column 29-34	Vertical deflection in prime vertical

4.1.4.3 Station Information File

The program searches for coordinate and height values in a station data file if they have not been entered in the adjustment file. The search is done by opening the file and stations without coordinates are searched for in the currently open file

If the file does not exist or the station cannot be found, the program computes the height using the available observations.

The files are opened in the following order using names that are determined by the program. They are opened in the working directory or using a path that has been specified in the option file explained in Section 3.1.4.1. For these files the keyword in the option file is 'data'.

The name of the station information files should be either 'stations.dat' or a name based on the input file with the extension '.stn'. The format should be the program station data format.

4.1.5 Values Entered With Decimal Points

Many of the values supplied to the program are interpreted as floating point values. Decimal points should not be included if there are no digits following. However, if decimal places are required, the decimal point must be entered. The decimal point is not assumed to be in any

particular position in the field, and the number of decimal places is limited only by the size of the field allocated for the value.

4.2 Output

The output of the program is stored in a disk file for inspection or for printing. The name of the output file is based on the name of the input file with the extension '.prt' or is the name entered on the command line used to run the program.

4.2.1 Options

Page 1 of the output shows the options requested in the option record. They are as follows:

- . Zone number.
- . Mean latitude.
- . Refraction option.
- . Default value for coefficient of refraction.
- . Default refraction coefficient standard deviation.
- . Number of iterations.
- . Analysis option.
- . Observation equation output option (If required).
- . Normal equation solution output option (If required)

4.2.2 Stations

This list shows the following information as interpreted from the '10' records and/or '18' records.

- . Adjustment number.
- . Station name.
- . Register number (For '18' records only).
- . Easting coordinate (Optional).
- . Northing coordinate (Optional).
- . Station height.

- . Station status ('FIXED' or left blank). The standard deviation is printed if entered.

4.2.3 Zenith Distances

This list shows the following information as obtained from the 23 records in the same order as in the input file.

- . Observation number.
- . 'From' adjustment number.
- . 'To' adjustment number.
- . Observed zenith distance.
- . Simultaneous reciprocal observation indicator if refraction option 3 is selected.
- . Height of instrument.
- . Height of target.
- . Identification number of occupied eccentric mark.
- . Eccentric height difference of occupied station.
- . Identification number of observed eccentric mark.
- . Eccentric height difference of observed station.
- . Reduced zenith distance.
- . Observed distance.
- . Observed distance type.
- . Reduced distance.
- . Reduced distance type.
- . Azimuth.
- . Computed zenith distance.
- . (C-O) in seconds.
- . Standard deviation.

4.2.4 Height Differences

This list shows the following information as extracted from the '24' records in the same order as in the input file.

- . Observation number.
- . 'From' adjustment number.
- . 'To' adjustment number.
- . Observed height difference.
- . Height of instrument.
- . Height of target.
- . Reduced height difference.
- . Height of occupied eccentric mark.
- . Height of observed eccentric mark.
- . Corrected height difference.
- . Computed height difference.
- . (C-O).
- . Standard deviation.
- . Weight.
- . Occupied eccentric mark number.
- . Observed eccentric mark number.

4.2.5 Matrix Information

After the observation equations have been computed, statistics indicating the size of the job are printed. The values shown are the numbers of stations, fixed stations, zenith distances and height differences followed by the number of observation equations formed, the order of the normal equation matrix, width of diagonal band and number of terms in normal equations.

4.2.6 Solution of Normal Equations

Each solution is printed together with its column number and the station number with which it is associated. For each adjusted station the first associated variable is a correction to the height and subsequent variables are 'k' value corrections for the refraction parameters used for the station. Units of height corrections are metres.

4.2.7 Residuals

The residuals on each observation after adjustment are listed with the sequence number of the observation and its 'From' and 'To' station numbers and names. Adjacent to this, the standard residual is printed. This is obtained by dividing the residual by the standard deviation. The length of the observed line is also printed. In addition to this, information giving the equivalent height or zenith distance residual is shown.

4.2.7.1 Summations

Two summations are printed out after the list of residuals. These are the sum of the weighted squares of residuals (the quantity to be minimised) and the sum of the weighted products of the residuals and the original right hand sides of the observation equations. If the adjustment is sound, these two quantities should be opposite in sign and significantly equal in magnitude.

The estimate of the variance factor is obtained by dividing this value by the number of redundant observations. The estimate obtained should be close to 1.0 if the standard deviations have been estimated correctly.

If the variance factor is less than 1.0 it indicates that the residuals are small in comparison with the estimated standard deviations of the observations. In this case the standard deviations should be reduced and the adjustment should be run again. If the variance factor is greater than 1.0 it indicates that the observation standard deviations have been under estimated or that there are large residuals on one or more observations.

4.2.7.2 Analysis

The summation of the residuals within intervals and maximum, minimum, mean and standard deviation of residuals are printed. One unit intervals up to four units are used for standard residuals. One second intervals up to four seconds are used for zenith distance residuals. For height residuals units of one millimetre, one centimetre or one decimetre are used. The program determines the unit to be used from the standard deviation of the residuals.

This information is printed in three sections. The first is for standard residuals of all observations, the second is for zenith distance residuals and the third is for height difference residuals.

4.2.8 Adjusted Heights and Refraction Coefficients

This section of output lists the height and 'k' values for each station after adjustment. The data shown for each station are the number and name, the register number (from the '18' records) and the provisional height, the computed correction and the adjusted values for height, the 'k' value and the 'k' standard residual. If a 'k' parameter has been allocated for each observation the observation number will also be shown adjacent to the appropriate adjusted 'k' value.

4.2.9 Adjusted Rotation Parameters

If the solution of rotation parameters associated with height difference observations have been requested, the provisional, the correction and the adjusted values will be printed. The rotation parameters have been labelled PHI and OMEGA.

Rotation parameter coefficients are computed using the difference between the grid coordinates of the stations connected. The PHI coefficient is computed from easting value and the OMEGA coefficient is computed from northing values.

The adjusted PHI parameter represents a rotation about the north-south axis and the adjusted OMEGA parameter represents a rotation about the east-west axis.

4.2.10 Matrix Output

If required the matrix of normal equations and its inverse can be printed. This facility was included mainly for testing purposes and should rarely be necessary, for normal jobs. The matrices are printed in upper triangular form.

4.2.11 Precision Analysis

This section shows the variance factor used and also the adjustment number, station name, register number (from the '18' records), adjusted height value and standard deviation and the adjusted 'k' values and standard deviations. If a 'k' parameter has been allocated for each observation the observation number will also be shown adjacent to the appropriate adjusted 'k' value.

4.2.12 Relative Height Analysis

This output shows the relative height precision between the stations in each observation used in the adjustment. The standard deviation for the height difference is computed and this is used with the distance between stations to determine the class. Distances can be entered in height difference observations for this purpose. The distance, standard deviations and class are shown in the output. The standard deviations are scaled by the factor 1.96 to determine a 95% confidence value.

4.2.13 Adjusted Stations

This section of the output lists, in alphabetical order, the names, adjusted heights and, if the precision analysis option is selected, the standard deviations of all the stations adjusted in the network.

4.2.14 Stations Held Fixed

This section of the output lists, in alphabetical order, the name and height of each station held fixed within the network.

5. PROGRAM ERROR MESSAGES

The program outputs a number of error messages related to the amount of data to be processed and also to provide information on data integrity. It has been designed to detect and report as many errors as possible in one run. This should allow the user to edit the data set to remove all inconsistent data in one editing session.

5.1 Program Capacity

Because of the arrays used for data storage within the program there are limits to the amount of data the program can process. These array sizes could be changed if required.

Maximum number of stations;

1000

Maximum number of observations
(Zenith distances and height differences);

6000

Maximum number of normal equations;

4000

For TRGLEVL the capacity is 2000 stations, 12000 observations and 8000 normal equations.

The following error messages are printed if the program capacity is exceeded in any of the above areas. Processing is then terminated.

5.1.1

*** TOO MANY STATIONS ***

More than 1000 stations have been entered. The program stops.

5.1.2

*** TOO MANY OBSERVATIONS ***

More than 6000 observations have been entered. The program stops.

5.1.3

*** TOO MANY NORMAL EQUATIONS ***

More than 4000 unknowns have been generated. The program stops.

5.2 File Initialisation

When the program starts it set up files to be used for data storage. Error messages associated with the initialisation of program files are as follows.

5.2.1

*** 01 RECORD MISSING ***

The '01' or options record is missing from the data. As it is used to select the options required for the adjustment, it is compulsory.

5.2.2

*** ERROR OPENING HEIGHT FILE ***

For stage four jobs a file for the storage of adjusted coordinates is opened in this section of the program for use later. This message indicates that this file cannot be opened.

5.3 Station and Observation Data

5.3.1

*** ERROR IN RECORD TYPE OR RECORD OUT OF ORDER ***

A record type not recognised by the program has been entered or a record of a certain type is not in the correct position in the input data.

If a station number appears in the observations but not in the station information, the observations will be printed, with the message.

5.3.2

*** OCCUPIED STATION NOT FOUND ***

or

*** OBSERVED STATION NOT FOUND ***

A station number given with an observation could not be found stored with station information.

5.3.3

*** STATIONS HAVE THE SAME CO-ORDINATES ***

An observation between two stations with the same coordinates has been found. An error would occur when computing the distance between them.

5.3.4

*** (C-O) VALUE TOO LARGE ***

The difference between the computed absolute term for a zenith distance observation or for a height difference observation exceeds the limit specified in the option record.

5.3.5

*** ERROR IN OBSERVED ZENITH DISTANCE ***

A value entered for an observed zenith distance is zero or contains illegal characters.

5.3.6

*** RECIPROCAL OBSERVATION NOT INCLUDED - "S" IGNORED ***

Refraction option 3 has been selected and the first observation of a pair of simultaneous reciprocal observations has been omitted.

5.4 Station Processing

Station information is printed in the order resulting from the re-arrangement for the minimisation of the bandwidth. The following messages can appear with the station information.

5.4.1

*** OMITTED ***

This is an advisory message to indicate that a station included in the data is not connected to another station in the network or the height for a station cannot be computed from the observations supplied.

5.4.2

INSUFFICIENT DATA TO COMPUTE HEIGHT

The program was not able to compute a provisional height for the station indicated. The station is omitted from the adjustment.

5.4.3

STATION DOES NOT APPEAR IN AN OBSERVATION

The program has checked all observations and has not found the station. The station is omitted to prevent a zero term occurring on the diagonal of the normal matrix.

5.4.4

STATION NUMBER HAS ALREADY BEEN USED

The number allocated to a station has already been allocated to another station. As this will cause a zero term on the diagonal of the normal matrix the station is omitted from the adjustment.

5.5 Normal Matrix Formation and Solution

5.5.1

The normal matrix is stored, solved and inverted in memory if it fits into the storage arrays available in the program. If the matrix is too large to be stored in memory, the program opens work files for matrix processing. If the work files cannot be opened the following message is printed.

*** UNABLE TO OPEN WORK FILES FOR MATRIX PROCESSING ***

This would most likely occur because of insufficient disk space.

5.5.2

The presence of zero terms on the diagonal of the normal matrix during the formation or solution indicates an unstable network. In this situation a solution cannot be obtained for the adjustment. The following error messages indicate such instability.

*** ZERO ON DIAGONAL IN COLUMN 'N' ***

During the formation of the normal equations a zero has occurred on the diagonal of the matrix in column numbered 'N'. This usually is the result of a station in the adjustment having no connections. The program checks for this at an earlier stage and omits any station which could cause this situation.

5.5.3

*** MATRIX SINGULAR - DIAGONAL BECAME ZERO IN COLUMN 'N' ***

*** STATION INVOLVED IS 'M' ***

During the solution of the matrix a diagonal term has become zero. The column number is shown as 'N' and the station number is shown as 'M'.

This usually occurs when a station is not fixed by sufficient observations. It indicates instability in the network in the vicinity of the station shown.

5.6 Geodetic Control Register

5.6.1

*** REGISTER NUMBER NOT ENTERED ***

The Geodetic Control Register number has not been entered for retrieval of station data from the Geodetic Control Register.

5.6.2

*** STATION HAS BEEN DELETED FROM REGISTER ***

The station for which data is to be retrieved from the Geodetic Control Register has been deleted from the register.

5.7 Reduction to Centre

5.7.1

*** NO ECCENTRIC DATA ON FILE FOR OCCUPIED STATION ***

or

*** NO ECCENTRIC DATA ON FILE FOR OBSERVED STATION ***

No eccentric data is available for the computation of reduction to centre of an observation.

5.7.2

*** ECCENTRIC ORIENTATION STATION (N) HAS BEEN DELETED FROM GCR ***

The orientation station used to orientate the set of directions to eccentric marks has been deleted from the Geodetic Control Register.

5.7.3

*** OCCUPIED ECCENTRIC HEIGHT NOT AVAILABLE ***

or

*** OBSERVED ECCENTRIC HEIGHT NOT AVAILABLE ***

The difference in height between the main station and the eccentric mark is not available for the reduction to centre.

Appendix A

Three sample input files are shown in this appendix to illustrate the use of the specific record types for each type of data. The record type is identified using the first two positions in each data record or the first three positions in the station label format. The data in these sample files are for demonstration purposes only and are not meant to be of sufficient quality to give a good adjustment result. These sample files can be copied and pasted into a text file and used for input to the program.

Sample Data File 1

Adjustment Heading

92V111
92WAGGA WAGGA

Options

01 055 3 0.005 35 3 2 2

Station Data

10 002	550893.784	6121110.049	WHEEL OF FORTUNE	496.3	0.1
10 003	538980.570	6094609.806	FLAKNEY	535.2	
10 004	506624.853	6096302.632	HANGING ROCK	554.4	0.1
10 006	-525049.208	6148811.607	KINDRA	316.710	
10 007	-516563.766	6136740.940	COTTEE	330.699	
10 008	-531984.378	6119905.841	BALD	305.995	
10 009	-527618.889	6114041.055	MOORONG	297.722	
10 010	-533796.625	6111991.819	WILLANS HILL	310.911	
10 011	555400.655	6071798.721	BURNGOOGIE	702.3	0.1
10 020	515997.610	6110479.102	YARRAGUNDRY	332.1	
10 021	524631.945	6122777.026	LIGHTHOUSE	389.7	
10 022	542663.594	6112713.232	KIAMBETH	237.1	
10 023	543613.171	6105081.467	GUMLY	344.1	
10 024	524633.706	6110749.550	POMINGALARNA	373.7	

Zenith Distance Data

23 002	008	0903842.7	3.0	0.070	0.245	0.250
23S008	002	0893004.7		0.070	0.235	0.110
23 002	010	0903710.6		0.070	0.015	0.270
23S010	002	0893145.2		0.070	0.222	0.335
23 002	009	0903334.2		0.070	0.230	0.255
23S009	002	0893741.9		0.070	0.235	0.335
23 004	024	0903231.4	3.0	0.068	1.850	0.330
23S024	004	0893812.9		0.068	0.155	1.850
23 008	021	0892528.9		0.068	0.235	0.195
23S021	008	0903818.9		0.068	0.235	0.000
23 009	024	0890234.1		0.069	0.236	0.000
23S024	009	0905951.8		0.069	0.235	0.000
23 009	021	0892801.4		0.088	0.175	0.270
23S021	009	0903601.2		0.088	0.244	0.335
23 009	020	0895325.8		0.039	0.120	0.255
23S020	009	0901233.1		0.039	0.235	0.335

23 024 021 0895822.3	0.036 0.180 0.270		
23S021 024 0900734.6	0.036 0.123 0.335		
23 020 004 0891836.0	0.054 0.160 1.998		
23S004 020 0904930.4	0.054 1.660 0.193		
23 003 023 0910033.0	0.055 1.665 0.194		
23S023 003 0890454.7	0.055 0.115 1.730		
23 022 010 0893413.6	0.052 1.760 0.196		
23S010 022 0903005.1	0.052 0.220 1.740		
23 008 023 0895642.1 5.0	1.524 4.300	-1.634	-1.241
23 023 010 0901138.7 5.0	1.646 3.960	-1.241	-1.652
23 023 010 0901139.5 5.0	1.676 3.926	-1.432	-1.652
23 023 022 0904859.6 3.0	0.160 1.628		
23S022 023 0891428.6	1.638 0.191		
23 023 010 0901228.5 3.0	0.160 0.000		
23S010 023 0895316.2	0.236 0.000		
23 023 002 0893431.1 3.0	0.230 0.191		
23S002 023 0903336.2	0.151 0.417		
23 022 002 0884734.2	1.635 0.191		
23S002 022 0911758.4 3.0	0.151 1.685		
23 023 022 0904909.2 3.0	0.236 1.520		-0.050
23S022 023 0891437.8	1.520 0.000	-0.050	
23 021 006 0901533.6 3.0	0.235 0.270		
23S006 021 0895621.7	0.239 0.245		
23 021 007 0901632.3	0.235 0.270		
23S007 021 0895120.9 3.0	0.239 0.245		
23 024 023 0900952.8 3.0	0.056 0.235 0.233		
23S023 024 0895936.1	0.056 0.187 0.191		
23 003 011 0894623.1 3.0	0.062 1.512 0.191	0.178	
23S011 003 0902654.4 3.0	0.062 0.235 1.605		0.178
23 003 011 0894617.2 3.0	0.062 1.490 0.285		
23S011 003 0902656.8 3.0	0.062 0.238 1.925		
23 009 003 0892850.2 3.0	0.050 0.135 1.870		
23S003 009 0904204.1 3.0	0.050 1.658 0.194		
23 010 003 0892129.4 3.0	0.055 0.165 1.930		
23S003 010 0904710.7 3.0	0.055 1.658 0.194		
99			

Sample Data File 2

Adjustment Heading

92V111
92WAGGA WAGGA

Options

01 055 3 0.005 35 3 2 2

Station Data

grd WHEEL OF FOR WHEEL OF FORTUNE	550893.784 6121110.049 496.3 0.1
grd FLAKNEY FLAKNEY	538980.570 6094609.806 535.2
grd HANGING ROCK HANGING ROCK	506624.853 6096302.632 554.4 0.1
grd*KINDRA KINDRA	525049.208 6148811.607 316.710
grd*COTTEE COTTEE	516563.766 6136740.940 330.699
grd*BALD BALD	531984.378 6119905.841 305.995
grd*MOORONG MOORONG	527618.889 6114041.055 297.722
grd*WILLANS HILL WILLANS HILL	533796.625 6111991.819 310.911
grd BURNGOOGIE BURNGOOGIE	555400.655 6071798.721 702.3 0.1
grd YARRAGUNDRY YARRAGUNDRY	515997.610 6110479.102 332.1
grd LIGHTHOUSE LIGHTHOUSE	524631.945 6122777.026 389.7

grd KIAMBETH	KIAMBETH	542663.594	6112713.232	237.1
grd GUMLY	GUMLY	543613.171	6105081.467	344.1
grd POMINGALARNA	POMINGALARNA	524633.706	6110749.550	373.7

Zenith Distance Data

zen WHEEL OF FOR	BALD	0903842.7	3.0	0.070	0.245	0.250
zenSBALD	WHEEL OF FOR	0893004.7		0.070	0.235	0.110
zen WHEEL OF FOR	WILLANS HILL	0903710.6		0.070	0.015	0.270
zenSWILLANS HILL	WHEEL OF FOR	0893145.2		0.070	0.222	0.335
zen WHEEL OF FOR	MOORONG	0903334.2		0.070	0.230	0.255
zenSMOORONG	WHEEL OF FOR	0893741.9		0.070	0.235	0.335
zen HANGING ROCK	POMINGALARNA	0903231.4	3.0	0.068	1.850	0.330
zenSPOMINGALARNA	HANGING ROCK	0893812.9		0.068	0.155	1.850
zen BALD	LIGHTHOUSE	0892528.9		0.068	0.235	0.195
zenSLIGHTHOUSE	BALD	0903818.9		0.068	0.235	0.000
zen MOORONG	POMINGALARNA	0890234.1		0.069	0.236	0.000
zenSPOMINGALARNA	MOORONG	0905951.8		0.069	0.235	0.000
zen MOORONG	LIGHTHOUSE	0892801.4		0.088	0.175	0.270
zenSLIGHTHOUSE	MOORONG	0903601.2		0.088	0.244	0.335
zen MOORONG	YARRAGUNDRY	0895325.8		0.039	0.120	0.255
zenSYARRAGUNDRY	MOORONG	0901233.1		0.039	0.235	0.335
zen POMINGALARNA	LIGHTHOUSE	0895822.3		0.036	0.180	0.270
zenSLIGHTHOUSE	POMINGALARNA	0900734.6		0.036	0.123	0.335
zen YARRAGUNDRY	HANGING ROCK	0891836.0		0.054	0.160	1.998
zenSHANGING ROCK	YARRAGUNDRY	0904930.4		0.054	1.660	0.193
zen FLAKNEY	GUMLY	0910033.0		0.055	1.665	0.194
zenSGUMLY	FLAKNEY	0890454.7		0.055	0.115	1.730
zen KIAMBETH	WILLANS HILL	0893413.6		0.052	1.760	0.196
zenSWILLANS HILL	KIAMBETH	0903005.1		0.052	0.220	1.740
zen BALD	GUMLY	0895642.1	5.0		1.524	4.300\
-1.634	-1.241					
zen GUMLY	WILLANS HILL	0901138.7	5.0		1.646	3.960\
-1.241	-1.652					
zen	WILLANS HILL	0901139.5	5.0		1.676	3.926\
-1.432	-1.652					
zen	KIAMBETH	0904859.6	3.0		0.160	1.628
zenSKIAMBETH	GUMLY	0891428.6			1.638	0.191
zen GUMLY	WILLANS HILL	0901228.5	3.0		0.160	0.000
zenSWILLANS HILL	GUMLY	0895316.2			0.236	0.000
zen GUMLY	WHEEL OF FOR	0893431.1	3.0		0.230	0.191
zenSWHEEL OF FOR	GUMLY	0903336.2			0.151	0.417
zen KIAMBETH	WHEEL OF FOR	0884734.2			1.635	0.191
zenSWHEEL OF FOR	KIAMBETH	0911758.4	3.0		0.151	1.685
zen GUMLY	KIAMBETH	0904909.2	3.0		0.236	1.520\
-0.050						
zenSKIAMBETH	GUMLY	0891437.8			1.520	0.000\
-0.050						
zen LIGHTHOUSE	KINDRA	0901533.6	3.0		0.235	0.270
zenSKINDRA	LIGHTHOUSE	0895621.7			0.239	0.245
zen LIGHTHOUSE	COTTEE	0901632.3			0.235	0.270
zenSCOTTEE	LIGHTHOUSE	0895120.9	3.0		0.239	0.245
zen POMINGALARNA	GUMLY	0900952.8	3.0	0.056	0.235	0.233
zenSGUMLY	POMINGALARNA	0895936.1		0.056	0.187	0.191
zen FLAKNEY	BURNGOOGIE	0894623.1	3.0	0.062	1.512	0.191\
0.178						
zenSBURNGOOGIE	FLAKNEY	0902654.4	3.0	0.062	0.235	1.605\
0.178						
zen FLAKNEY	BURNGOOGIE	0894617.2	3.0	0.062	1.490	0.285
zenSBURNGOOGIE	FLAKNEY	0902656.8	3.0	0.062	0.238	1.925
zen MOORONG	FLAKNEY	0892850.2	3.0	0.050	0.135	1.870
zenSFLAKNEY	MOORONG	0904204.1	3.0	0.050	1.658	0.194
zen WILLANS HILL	FLAKNEY	0892129.4	3.0	0.055	0.165	1.930
zenSFLAKNEY	WILLANS HILL	0904710.7	3.0	0.055	1.658	0.194

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Sample Data File 3

Adjustment Heading

92 TRGLEV TEST DATA
92 LEVALS ADJUSTMENT

Options

01 3 3 2 2 1

Station Data

stn*SSM6099	SSM6099	2.672
stn*SSM28740	SSM28740	99.191
stn*SSM11395	SSM11395	43.805
stn*SSM6107	SSM6107	58.533
stn*SSM6103	SSM6103	20.885
stn*SSM6102	SSM6102	13.789
stn*SSM6101	SSM6101	23.783

Vertical Angle Data

ver	PM47310	PT MACQUARIE	001356.8	2.0	10431.084S	1.860	0.210
ver		WAUCH	013315.5		10444.642S		
ver		PM47311	004349.0		4197.401 S		1.870
ver	CAIRNCROSS (WAUCH	-003751.7		17949.138S	0.230	0.210
ver	COMBOYNE (P)	WAUCH	-010620.5		16984.097S	0.235	1.455
ver		KEW (P)	-015252.0		13302.522S		1.430
ver	PM47316	JOLLY (P)	014610.8		7334.950 S	1.940	1.105
ver		KEW (P)	031537.0		3928.770 S		1.055
ver		KEW (P)	031524.0		3928.770 S		0.680
ver		JOLLY (P)	014547.8		7334.950 S	1.880	
ver	PM47315	WAUCH	020240.6		9615.049 S	1.800	0.210
ver		JOLLY (P)	020239.8		6609.080 S		0.410
ver	PM47312	PM47311	-023948.5		274.367 S	1.610	1.580
ver		JOLLY (P)	004807.3		7822.534 S		1.055
ver		PT MAC TRIAN	-000758.8		11800.027S		1.470
ver		PM47310	-005308.1		4468.335 S	1.880	1.630
ver		PT MAC TRIAN	-000757.8		11800.027S		1.625
ver	JOHN (P)	KEW (P)	-014659.1		10371.329S	0.235	0.205
ver		COMBOYNE (P)	001649.5		18218.505S		1.035
ver	JOLLY (P)	PM47316	-014925.2		7334.950 S	0.240	1.690
ver		CAMDEN HAVEN	012932.2		9074.586 S		1.430
ver		PM47312	-005128.1		7822.534 S		1.640
ver		PT MACQUARIE	-003014.4		17039.588S		0.210
ver		WAUCH	002808.6		12285.464S	0.226	0.210
ver		PM47318	-011251.0		11492.444S		1.500
ver	KEW (P)	PM47317	-024501.7		4419.368 S	0.240	1.850
ver		JOHN (P)	014202.9		10371.329S		0.230
ver		PM47318	-014817.3		7385.316 S		1.580
ver	KEW DUMPY	PM47315	-024938.4		4734.906 S	1.500	1.600
ver	PM47317	KEW (P)	024306.2		4419.368 S	1.730	0.200
ver		JOHN NAIL	032044.9		8899.737 S		1.600
ver	PT MACQUARIE	PM47310	-001900.0		10431.084S	0.235	1.630
ver	PT MAC TRIAN	PM47311	-000120.2		11636.082S	1.633	1.640
ver	PM47311	SSM28740X	-004723.5		1669.569 S	1.850	1.580
ver	PM47318	KEW (P)	014516.8		7385.316 S	1.570	1.055
ver		JOLLY (P)	010745.8		11492.444S		1.055
ver		CAMDEN DUMPY	054129.1		4777.634 S		1.600
ver	WAUCH	PM47311	-012730.0		9519.878 S	0.220	1.770
ver		JOLLY (P)	-003353.7		12285.464S		0.210

ver JOLLY GIP	PM47313	-021343.0	4881.613 S	1.670 1.430
verSPM47313	JOLLY GIP	021119.1	4881.613 S	1.730 1.670
ver JOHN (P)	CAMDEN HAVEN	-002420.4	10663.375S	0.235 1.055
verSCAMDEN HAVEN	JOHN (P)	001938.2		0.230 0.190
ver PM47312	PM47311	-023948.5	274.367 S	1.610 1.580
verSPM47311	PM47312	023743.4		1.630 1.510
ver CAMDEN DUMPY	PM47318	-054341.5	4777.632 S	1.580 1.490
verSPM47318	CAMDEN DUMPY	054136.0		1.505 1.550

Height Difference Data

dif SSM11395	PM47310	23.401	0.013
dif SSM28740	SSM28740X	0.124	0.001
dif SSM6107	PM7314	3.446	0.001
dif	PM47313	0.528	0.008
dif SSM6103	PM47315	-12.019	0.002
dif SSM6102	PM47316	4.015	0.0001
dif SSM6101	PM47317	7.115	0.005
dif SSM6099	PM47318	10.234	0.009
dif JOLLY (P)	JOLLY GIP	-1.866	0.001
dif KEW (P)	KEW DUMPY	-2.323	0.001
dif JOHN (P)	JOHN NAIL	-2.582	0.001
99			

Sample Data File 4

92CCD Test
01 56

1.0

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2

geo*TS5933	BRUNSWICK	-28 31 29.59007	153 32 17.30597	96.83
geo TS5129		-28 21 43.70119	151 58 50.43097	835.907
geo TS5596		-29 36 55.86616	151 50 45.89932	1260.019
geo TS6773		-29 51 42.31467	153 16 04.56734	11.538
geo TS5821		-31 50 36.58469	152 45 12.34357	54.87
ccd TS5933	TS5129	61619.2131	139879.509815508.1012	
ccd TS5933	TS5596	126875.9129119923.5538	-106228.8740	
ccd TS5933	TS6773	76460.1018	-8895.5980 -129310.8441	
ccd TS5933	TS5821	199159.920	-16165.387 -317941.235	
ccd TS5933	TS6773	76460.017	-8895.428 -129310.934	
ccd TS5129	TS5933	-61619.414	-139879.505-15508.170	
ccd TS5933	TS5821	199160.239	-16165.502 -317941.121	
ccd TS5933	TS6773	76460.160	-8895.400 -129310.896	
ccd TS5129	TS5933	-61619.336	-139879.421-15508.174	