New Zealand
Agricultural
Engineering
Institute

CONTOUR HANDBOOK

A GUIDE TO LAND CONTOURING USING THE COMPUTER PROGRAMME CONTOUR

Project Report : 27
G.J. Harrington
June 1982

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A guide to land contouring using
the computer program "Contour"

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PROJECT REPORT NO. 27

ISSN-0077-9547

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CONTOUR HANDBOOK

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1.0 INTRODUCTION

The aim of this handbook is to give a practical surveyor sufficient information to perform a contour survey using the computer programme called CONTOUR. This program is designed to produce contours of irregularly spaced stadia field readings. The programme is currently implemented at Lincoln College. A programme listing (FORTRAN) is available from the author.

A full explanation is given here of the surveying technique required to survey using CONTOUR and the features it offers. This is followed by a detailed summary of how to fill the computer booking sheets; interpretation of computer output; and additional features of CONTOUR not normally required for ordinary surveys. The information given is fairly detailed so the reader who wishes merely to refresh his memory on how to fill the booking sheet is referred to Section 12.

The instructions are presented assuming the surveyor has no knowledge of computers although a working knowledge of stadia surveying techniques is necessary.

The system is designed to be used with a surveyor's level or theodolite.

This handbook has been compiled after the system has been used to contour many thousand hectares of land on a wide range of terrain types.

The cost of contouring using this system is comparable with or cheaper than other manual systems unless the terrain is very even and the contour interval is very large (e.g. contour lines greater than about 100 m apart). In this case, direct contouring onto scaled aerial photographs may be cheaper. The main disadvantage of manual contour drawing is that the basic terrain data is not available for subsequent computer design work.

2.0 APPLICATIONS

The surveying programme CONTOUR was designed for processing field survey data to produce a line printer contour plan. In particular, it was designed for agricultural land surveys to provide contour plans to aid the design of irrigation schemes, farm dams and farm drainage. Its use is not, however, restricted to these applications.

Once the terrain data is stored in the computer it can be used by other programmes for other computer tasks such as volume estimation for engineering works, estimation of pipe sizes for drainage and irrigation schemes or for three dimensional visual displays. (See Figure 17).

3.0 SPECIAL FEATURES

Unlike any other computer contouring system, CONTOUR makes use of the recording sequence of the field spot heights.

Consecutive field spot heights are joined to form a profile of the terrain rather than simply a series of isolated spot heights. This enables the surveyor to pass more information to the computer and overcomes the problems that other contouring programmes experience where there are abrupt changes in the terrain. In particular, CONTOUR is able to produce realistic contours of sharp valleys, ridges and terraces which would otherwise appear as a series of dimples or humps on other computer contouring systems.

The profiling technique requires spot heights to be recorded at changes of grade only, rather than at regular intervals and hence less field data need to be recorded.

Landmarks such as fencelines may be recorded in the field and these are automatically shown on the contour plan.

A major problem with computer drawn contours is that errors which would be identified in the process of manual plotting can be missed. CONTOUR has been programmed to identify logical errors with a warning message on the printout. A further check can be made by observing the printout of profiles (see Fig. 13). This printout shows the path of the staffman during the course of the survey. Booking errors generally displace the spot height from its true position and hence any deviations from the known survey pattern indicate an error.

4.0 SURVEY TECHNIQUE

The surveying technique to adopt with CONTOUR is to survey in such a way that profiles (i.e. the paths of the staffman) next to each other enclose a space of fairly regular terrain. The computer programme CONTOUR can then quite correctly estimate spot heights between the profiles and construct a realistic contour plan.

On very even terrain a regular surveying pattern can be adopted where parallel profiles are surveyed usually at about 40 m apart. Figure 1 shows the method of surveying such areas.

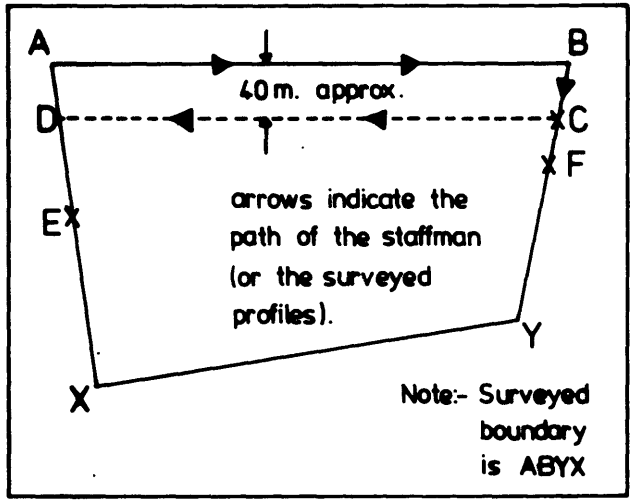

Figure 1. Surveying Regular Terrain

Referring to Figure 1: after marking position D a series of levels (i.e. a profile) is taken beginning at A and recording

spot heights at any changes of grade to point B. Note that is is not necessary to survey at regular intervals, however, a maximum distance between spot heights is suggested below. (Figure 4). After recording position B, the staffman marks position F with a flag. He then returns to position C and continues the profile from C to a flag at D and then marks position E. Note that the profile need not be straight. The process is repeated until the whole area A B Y X is completed.

On complex terrain the irregular areas are surveyed first. The rest of the even topography may then be surveyed using a regular pattern which may, if necessary, cross the earlier survey of the irregular area. (See Figure 2).

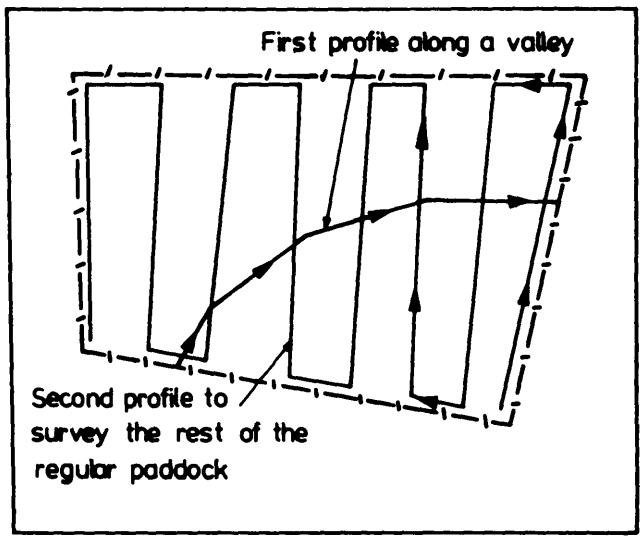

Figure 2. (a) Surveying An Area Containing a Valley

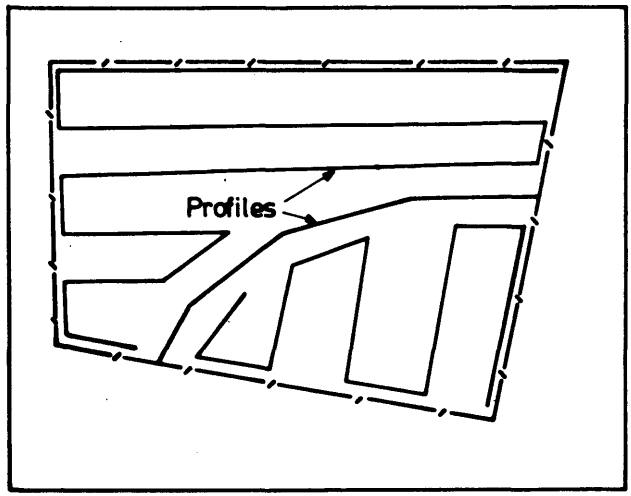

Figure 2 (b) Alternative Surveying Pattern

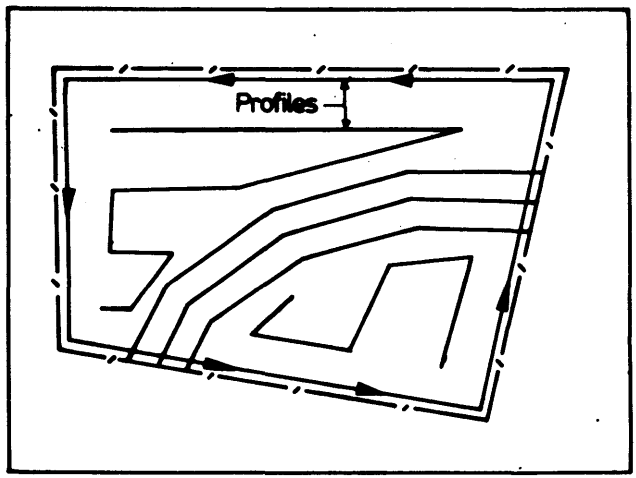

Figure 2 (c) Alternative Surveying Pattern

Note 1. In this case the valley has a sharply defined intersection with the surrounding regular terrain.

Note 2. A profile around the boundary as shown here helps to sharply identify the boundary on the plan.

When survey profiles cross, the first profile takes precedence and the second profile is discontinued by CONTOUR at the closest spot heights on either side of the first profile. (See Figure 3).

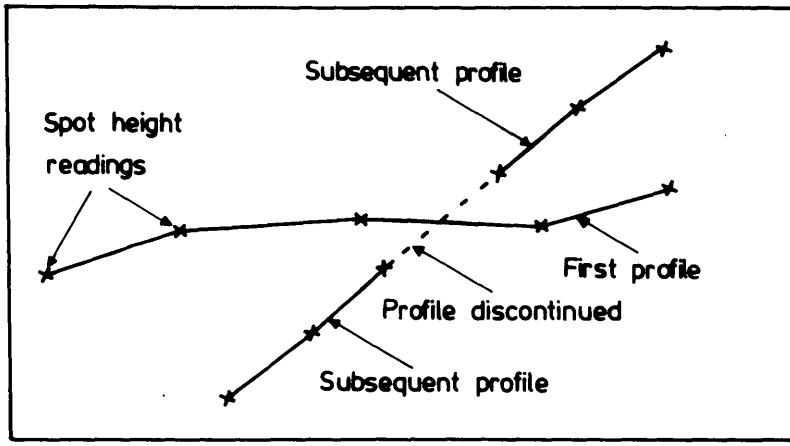

Figure 3. Profiles Crossing

It is suggested above that the survey profile pattern should be regular. This is not essential but it will help to ensure that no areas are missed. It also helps to identify errors on the plan as they stand out very clearly when the survey pattern is regular.

Some judgement and experience is necessary to decide whether or not to run a profile along a valley before doing the rest of the survey in an otherwise regular area.

As a general guide, however, if the valley or other discontinuity does not have any sharply defined boundaries or centre and has an overall width of about twice the normal profile separation for that survey, then a separate profile along the length of the discontinuity is probably unnecessary.

No attempt should be made to contour a very narrow ditch (say less than 2 m wide) on a normal plan scale of about 1:2000. Non-contour spot heights (See Section 8) can be used to determine its invert level and its position can be identified by landmark characters. (See Section 7).

To aid the mobility of the staffman it has been common to use a two or three wheeled motorcycle for the field survey work.

5.0 INTENSITY OF SPOT HEIGHTS

As stated above, spot heights should be recorded at significant changes of grade along the profiles. Note that it is not necessary to survey individual spot heights at regular intervals. The profiles should be as close as is necessary to give a sufficiently accurate indication of the terrain surface, for the purposes of the survey or according to the survey specifications. The profile separation for normal agricultural surveys (scales 1:2000 or 1:1000) are generally in the range of 30 m to 50 m. The profile separation may vary within a survey according to the roughness of the terrain.

The programme CONTOUR does place some restrictions on the maximum and minimum distance between spot heights. These restrictions, discussed below, generally do not interfere with a normal survey and the penalties described below for breaking these rules are not serious.

Should the distance between consecutive readings be greater than that given in Figure 4 below, there is a risk that the segment of the profile between the two spot heights may not be created by the programme. This can easily be seen on the computer printout and can be corrected and reprocessed if necessary. If the profiles are too far apart the area between them may not be contoured. (Discussed further in Section 16.6).

Should the minimum distance between the spot heights in the field be less than recommended in Figure 4 then they may be averaged and appear as one point on the line printer output.

PLAN SCALES	1:500	1:1000	1:2000	1:5000
Maximum distance between consecutive readings or adjacent profiles	25 m	50 m	100 m	250 m
Minimum distance between consecutive readings or adjacent profiles	1.25 m	2.5 m	5 m	12 m

Figure 4. Distances Between Spot Heights or Profiles

6.0 MAXIMUM NUMBER OF SPOT HEIGHTS

A maximum of 500 field spot height readings in each survey is allowed for in CONTOUR. From a practical point of view, it is usually better to limit the number of spot heights to about 300 per survey so that one single error will not cause a large processing job to be re-run.

Another version of CONTOUR called CONTOURB is designed to process a maximum of 2000 field spot height readings if necessary.

It is advisable to limit the first survey with this system to not more than 200 readings and that it be processed (and corrected if necessary) before attempting to survey any other areas. At the normal spot height intensity this would represent an area of about 15 to 20 hectares.

7.0 RECORDING LANDMARKS

Every opportunity should be taken to identify on the computer plan the spot heights which are taken near landmarks such as a fence, a tree, a pile of stones, a local high or low spot, a drain, a creek etc. This can be done by writing an alphabetic character in the "F" column of the booking sheet alongside the appropriate reading. This character will then be printed out in the correct position on the computer plan. Because F is commonly used to mark fencelines, these alphabetic characters have commonly been called "F Characters" or "Landmark Characters".

The characters A, B, C and I should be avoided as these are automatically used by CONTOUR to mark the following positions:-

- The initial staff position (A); which is always a reading onto a bench mark (BM) or a temporary bench mark (TBM). This BM or TBM should always be either inside or within a few metres of the surveyed area to reduce the computer processing time of the survey.

- The final staff position in the survey (B); which may be a reading back onto the initial bench mark. A horizontal and vertical survey close is always calculated using these two readings (A & B) but there is no processing penalty if a good close is not achieved.

- Survey change points (C); The position of the change points on the fore-sight before the change of instrument position is marked using the C character.

- Survey instrument positions (I); There is no need for the surveyor to make a special effort to mark the position of the survey instrument on the plan.

8.0 MANIPULATING PROFILES

Every spot height recorded by the surveyor is considered by CONTOUR as a ground spot height on a profile unless indicated otherwise by the surveyor in the "$" column on the field booking sheet. There are three characters which can be used by the surveyor in the "$" column.
These are $, N and D.

- $ Option (See Figure 5a)
  "$" is used alongside a reading to indicate that the profile is to be discontinued between this point and the next staff position. (A $ associated with each staff reading would cause all the spot heights to be processed as individual spots instead of being joined to form profiles.) The $ option is normally used to break a profile where it is necessary to travel to another sub-area in the survey or where for any reason the profile, which would be generated by joining any two spot heights together, would not be a true representation of the landform. This is also true of change points or bench mark readings. The symbol "$" can be thought of as a "sequence break".

- N Option (See Figure 5b)
  "N" is used to enable the surveyor to take a reading which is not to be used by CONTOUR for estimating the position of contour lines. For example, if a BM or a TBM is not at or near ground level then the N option should be used to ensure it does not affect the contour lines. This is also true of change points, invert levels in narrow ditches and any readings taken on the top of fence posts etc.

  If an N option reading is not associated with a land-mark character (see Section 7) the position of

the reading will not appear on the computer plan. It is generally desirable to have all N option spot heights marked on the plan.

The symbol "N" can be thought of as "non-contour". It causes the profile to be broken off between the spot heights both before and after the particular non-contour spot height. It would be inappropriate to have a profile connected to non-contour spot height.

- D Option (see Figure 5c)

"D" is used so that a non-contour spot height can be recorded and the profile line be continued between the spot heights immediately before and immediately after the non-contour spot height. It can be used to mark a pipe invert or a non-contour change point or any other non-contour spot height.

Several D option readings may be recorded consecutively if required.

As for the N option, a landmark character should be used with a D option reading.

The symbol "D" can be thought of as a "deviation" for a non-contour spot height.

If it is ever necessary to deviate from a profile to record a ground contour spot height or a second profile then this must be done using the $ option to discontinue the first profile and a $ option to discontinue the second profile. When returning to the initial profile, a reading is taken at a distance just greater than the minimum separation of spot heights (See Figure 4) from the last initial profile reading. The initial profile can then be continued without a significant interruption. (See Figure 5d)

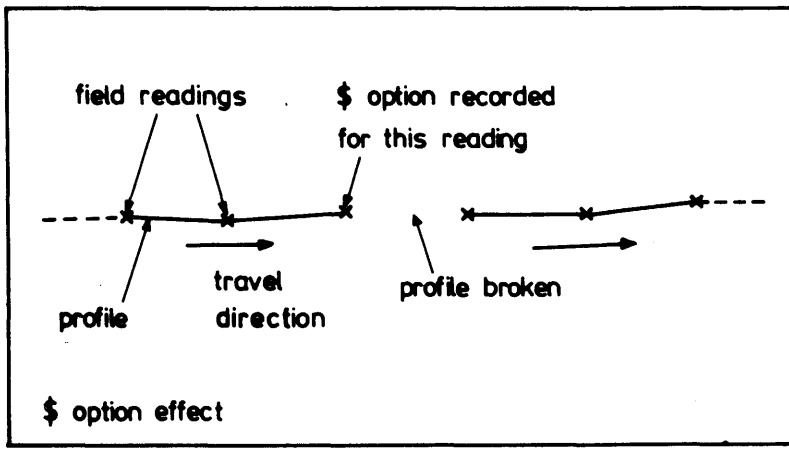

Figure 5a. $ option effect

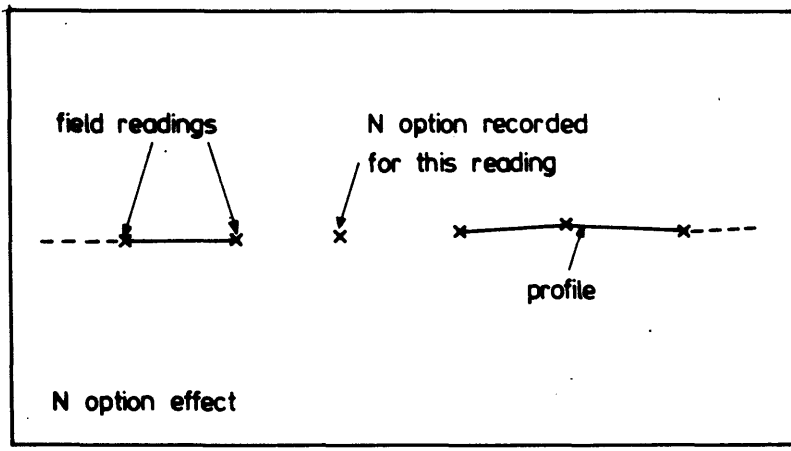

Figure 5b. N option effect

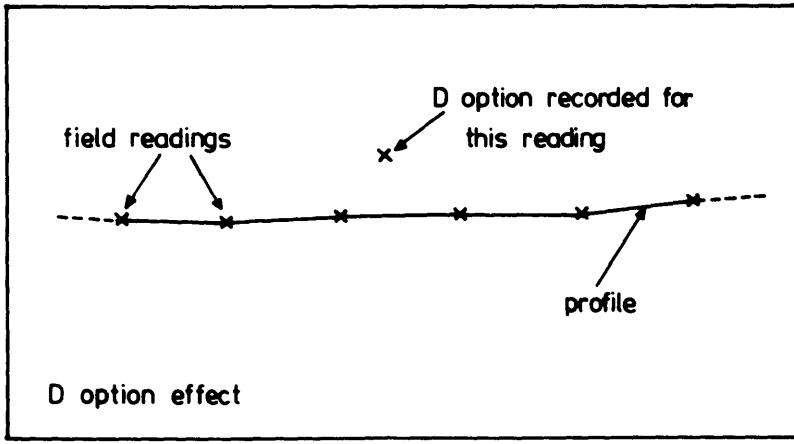

Figure 5c. D option effect

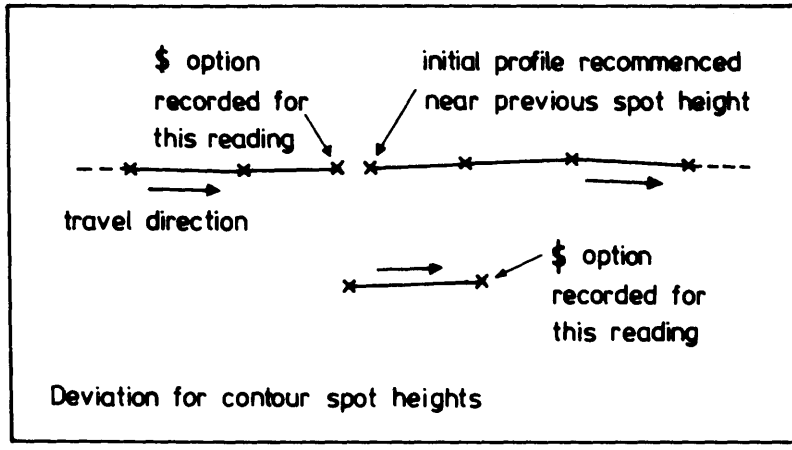

Figure 5d. Deviation for contour spot heights

9.0 CHANGING INSTRUMENT POSITION

The surveying instrument position may be changed as many times as desired during the course of a survey provided that the correct procedure is used. Generally it is undesirable to change more than two or three times during the course of one survey because the cumulative effect of minor errors in orientation may lead to an incorrect plan. No attempt is made by CONTOUR at traverse adjustment.

The instrument change technique adopted for CONTOUR is to read two change points at any time before the change of instrument position (fore sights) and then to record the two change points immediately after changing the instrument position (back sights).

The change points are always numbered on the booking sheets as "1" and "2" but may be read in any order provided that the change points retain the same number before and after the instrument change. No other numbers or letters are used to identify change points.

Change points should be selected so that there is a bearing angle difference of not less than about 15^{o} (preferably 30^{o} to 40^{o}) between the spot heights both before and after the change of instrument position. (See Figure 6). The greater the difference in bearing angle, the more accurate the change of instrument position is likely to be. It is generally better to have the two change points on a line at approximately right angles to the line joining the two instrument positions as this will also aid accuracy.

The orientation of the horizontal circle at the initial instrument position determines the orientation of the plan on the page. At all subsequent instrument positions the horizontal

circle orientation has no significance at all. This is discussed further below. (See Section 10).

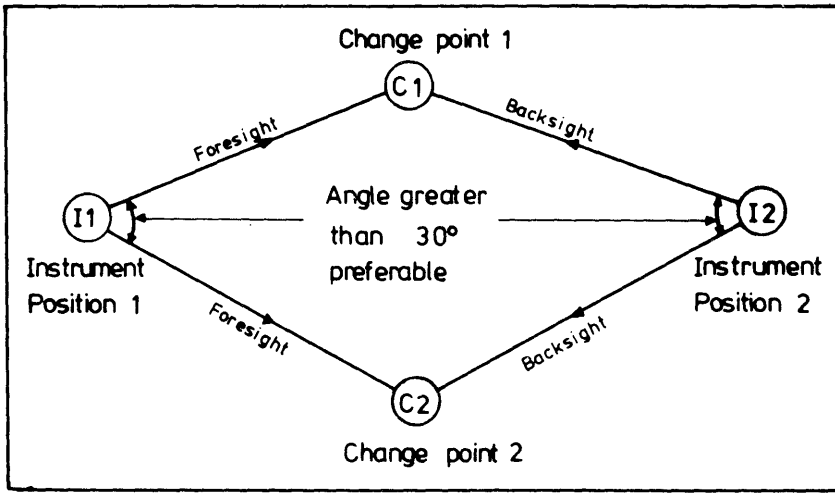

Figure 6. Change point Procedure

Most of the serious errors in surveying occur at change points. To reduce the risk of error, both stadia hairs should be read at change points where this is at all possible.

The first change point recorded following the change of instrument position determines the new instrument height. The second reading serves as a cross check on the height and fixes the new instrument position on the plan.

In the event of a major error at a change point it is possible to separately process the data before and after the error provided that the new instrument height can be established. The separate plans can later be manually recombined.

10.0 ORIENTATION OF THE COMPUTER PLAN

As mentioned above (Section 9) the orientation of the computer contour plan depends on the orientation of the horizontal circle at the initial instrument position in a survey. The bearing of zero at this initial instrument position always points down the computer page. (See Figure 7).

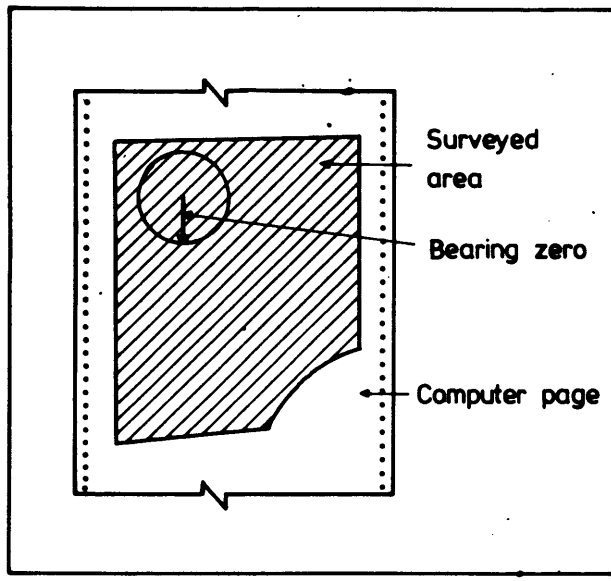

Figure 7. Plan Orientation

It is recommended that the horizontal circle be orientated to be parallel with the longest straight boundary. This will align the plan on the computer page to give the least number of strips of computer printout and the least cost to process.

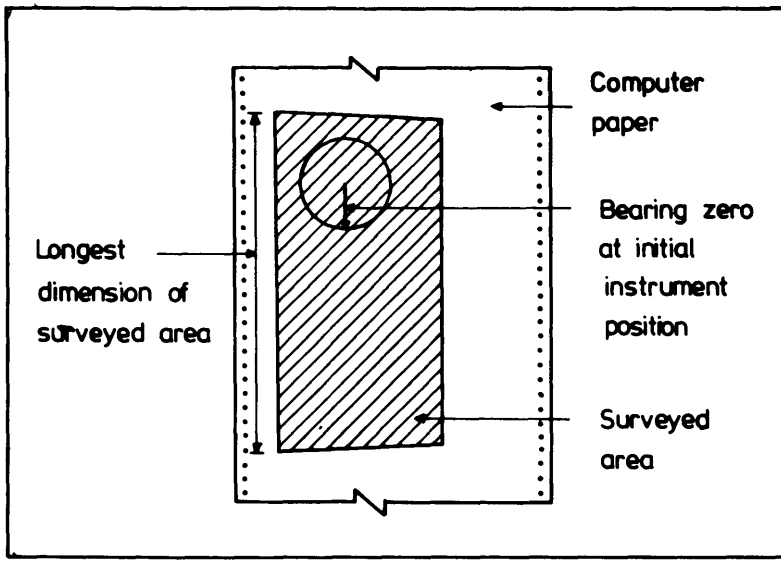

Figure 8. Plan Orientation for Minimum Processing Cost

There is no limit to the size of the plan produced by CONTOUR. If the area is too large to fit on one strip then the rest of the survey is automatically printed on a second, third or further strip of paper. The whole area can then be compiled by joining the strips together. (See Figure 9).

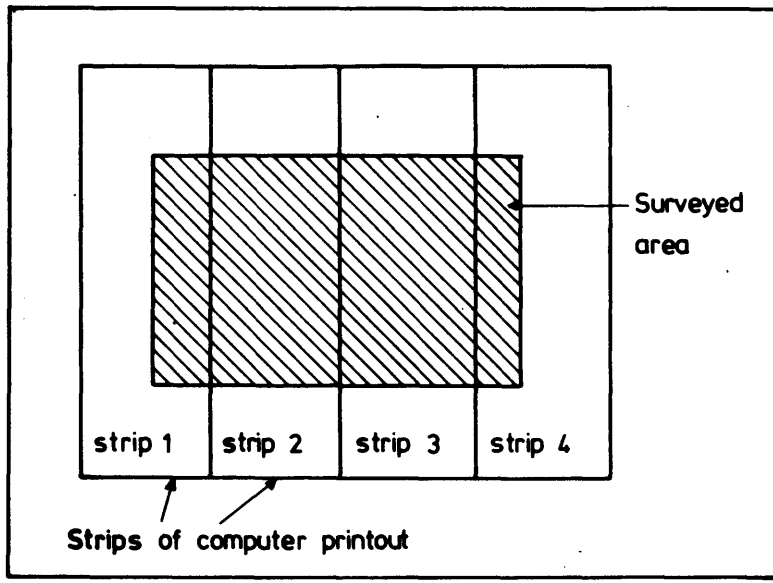

Figure 9. Plans too wide for one strip of paper

11.0 DATA PROCESSING STEPS

This section gives an overview of the steps in processing the data for a contour survey.

(a) The field survey is booked onto specially prepared booking sheets.

(b) The recorded field data is punched onto computer cards (or directly onto a computer disk file in card image format)

(c) The field information is processed by CONTOUR to give output on a computer printer as follows:-

- All the field readings are tabulated. Alongside these are the reduced level, X and Y co-ordinates and the character(s) which will be used to indicate the position of each spot on the plan. (See Figure 11).
- A line printer plan is made of all the individual spots recorded in the field to the specified plan scale. This is called "STAGE 1" (See Figure 12).
- A plan is made of all the profiles recorded in the field. This is called "STAGE 2". This plot is particularly useful for identifying errors in the survey because it shows the path travelled by the staffman. (See Figure 13).
- A line printer plan is made of the contours. This is called "STAGE 3". (See Figure 14).

The "stage" to which the data is processed can be specified on the booking sheet. The stage numbers 1, 2 or 3 will cause CONTOUR to process the data up to and including the specified stage.

The form of the computer output is discussed further in Section 15.

12.0 RECORDING FIELD DATA

It is essential that the booking sheet be neatly and clearly filled in. The field readings are generally punched onto computer cards or disks from these sheets. The cards are punched exactly as the data is presented, so it is essential that the booking sheets are also correctly filled in.

Experience has shown that rough field readings which are tidied up and transferred to a new booking sheet invariably contain errors associated with transferring the data. Transferring data onto other sheets is also time consuming, so the practice should be completely avoided by booking the data neatly and correctly in the field.

If an error is made in recording data in the field, the whole line should be crossed out re-written to avoid any confusion.

Never photocopy the booking sheets. Use only the printed sheets provided. The relatively poor resolution and colour of photocopied sheets makes them more difficult for the card punch operators to read.

Other points to note:-

- Use ballpoint pen for clarity.
- All printing in block letters (i.e. upper case or capital letters).
- Print one number or letter only in each square on the booking sheet.
- Numbers should be written around the decimal points where these are given.
- Where no decimal points are shown, the numbers should be printed in the squares as far to the right of the allocated space as possible.
- No additional decimal points are allowed except in the TITLE and REMARKS areas.

COMPUTER STADIA SURVEY BOOKING SHEET

Use ball-point pen

Title: SURVEYING EXAMPLE 9/5/90 Date: JONES CHRISTCHURCH Surveyor: Office:

Radius: 500.0 Stage: 3

Scale: 2000.0 to one Contour Interval: 0.5 R.L. Bench Mark: 169.54

Axial hair	Stadia hair	Stadia hair	Bearing Deg	Bearing Min	Bearing Sec	Vertical Deg	Vertical Min	Vertical Sec	a/c	F	S	Seq	Remarks	Sheet No
1.000	1.995	0.005	203	40							N		BM1	1
1.500	2.224	0.776	134						1		N			
2.355	3.339	1.331	87						2		N			
2.000	2.663	1.337	64						2					
1.115	1.995	0.355		0	40				1					
3.000	1.002	.	343							F				
3.440	1.440	.	345											
3.008	1.115	.	348											
3.337	1.488	.	355											
3.776	1.990	.	358							F				
2.667	0.883	.		6										
2.997	1.111	.		13										
3.083	1.114	.		22						F				
2.913	1.226	.		26										
2.772	1.331	.		33										
1.996	0.774	.		42										
1.332	2.447	.		47						F				
1.554	0.552	.		63										
1.336	0.338	.		77						F				
0.955	1.881	.	101											
0.866	1.788	.	122											
1.007	2.111	.	132							F				
1.554	1.552	.	133											
0.855	1.779	.	136											
0.337	1.223	.	141											

Fill in title, scale etc. on the first sheet of each complete survey. Upper-case letters only. One letter per square.

Figure 10. Survey Booking Sheet

The following description of the areas of the booking sheet refers to Figure 10.

Note that the first two lines on the booking sheet which contain the title and scale etc., should be filled in on the FIRST SHEET ONLY of any complete survey.

TITLE - The title, date, surveyor and location should be entered here. This whole title block will appear several times on the computer output. Each title should be unique in some way.

RADIUS - This is the "computer search radius". It should be specified as the estimated maximum distance in metres between the surveyed profiles. The smaller this distance, the cheaper the processing cost. (Further information is presented in Section 16.8).

STAGE - This is either 1, 2 or 3. (See Section 11).

SCALE - This is the plan scale desired. Using the decimal point provided, a scale of 1:2000 is written as 2000.0 in the sheet. Recommended scales for agricultural engineering applications are:- agricultural irrigation 1:2000, horticultural irrigation or other development work 1:1000, farm dams 1:1000 or 1:500, drainage 1:1000. See Note 5 below.

CONTOUR INTERVAL - This is the contour interval of the contour plan in metres. Recommended contour intervals for various agricultural engineering applications are:-

farm drainage 0.1 m, surface irrigation 0.25 m, farm dams 0.5 m or 1.0 m, trickle irrigation 1.0 m, sprinkler irrigation 1.0 m, (See Note 5 below).

R.L. BENCH MARK - This is the reduced level of the bench mark. This height is assigned to the very first staff position in the survey.

AXIAL HAIR - Survey instrument axial hair reading. (See Note 2 below).

STADIA HAIR - Survey instrument stadia hair reading. The top or bottom stadia hair reading can be entered in either column. When only one stadia hair is being used it should be entered in the left hand stadia hair column. This makes the data easier to punch from the booking sheet. Both stadia hairs should be used at change points as a check on accuracy.

BEARING - The bearing in degrees, minutes and seconds is written using the spaces as far to the right as possible in each column. (Seconds are seldom necessary for bearings but are important for vertical angles).

VERTICAL - The vertical angle in degrees, minutes and seconds is writen using the spaces as far to the right as possible in each column. It is assumed that 90^{o} or 270^{o} refer to horizontal. If this is not correct, then a vertical circle correction must be made. (See Section 16.9).

CP - The number "1" or "2" is entered here to indicate that the reading is a change point (See Section 9).

F - This column is used to specify a landmark character (See Section 7). Every opportunity should be taken to record landmarks such as fences etc.

$ - This is the column used to manipulate the profiles and may contain the characters $, N or D (See Section 8).

SEQ - This column was used to sequence the readings. Experience has shown it is better to leave it blank. (Further information in Section 16.5).

REMARKS - Any remarks may be entered in this space using block letters with only one letter per square. Excessive use of this area should be avoided to reduce data punching time. The most frequent use of this area is to define a landmark character. Where a definition is necessary it should be done for the first landmark character of that type only, e.g. "T" in the landmark column may be defined as TREE in the remarks column. These remarks are printed out by CONTOUR along with the field reading. This area can also be used to further identify the bench mark or the change points.

SHEET NO. - The booking sheets are numbered using this space. It can be used to keep the booking sheets in order but its main use is to help

in cross referencing from the booking sheets to the computer printout. The sheet number is treated as a remark and is printed out by CONTOUR with the remarks. (See Note 1 below).

Note 1: The first line of readings which contains SHEET No. may be used for any spot height. A common error is to use this line for only the initial reading onto the bench mark. If this line is not used then the sheet number is not able to be used as shown, and CONTOUR may halt the processing of the data (as in Note 2).

Note 2: The programme CONTOUR will consider the survey is complete if all the axial hair and both stadia columns are either zero or blank. It will then construct the plans etc., using the spot heights recorded up to that point.

Note 3: All <u>blank spaces</u> in the areas where numeric data (numbers) are written (e.g. Axial hair, Stadia hair, Bearing, Vertical) are considered by CONTOUR to be zero.

Note 4: The first reading of every survey must be of a bench mark. The last reading of each survey is assumed by CONTOUR to be of the same bench mark and the horizontal and vertical closes are calculated accordingly. There is no penalty, however, for a wide misclose as could occur if the final reading was not onto the bench mark.

Note 5: The contour interval should be sufficiently fine so that any irregularities which are important for the particular application cannot be "hidden" between the contour lines. The scale should be chosen so that the necessary contour interval does not produce a confusing or crowded contour plan.

13.0 FIELD DATA CHECKS

As CONTOUR processes the data it makes a number of checks to help identify logical errors in the survey. If an error is identified, then an error message is printed along with the data. If the error is very serious the processing may be limited to a printout of the data and reduced levels. This is to avoid unwanted and unnecessary computer printout. If the error is less serious but a plan would be helpful in identifying the error then the processing may be limited to stage 2. If the error is trivial then there is no restriction on the processing stage. Generally, there is no need to worry that some small data error will cause a huge usage of computer time or paper.

The following situations will result in a warning message:-

- Where the profile length between spot heights is greater than given in Figure 4. This is a very useful check for identifying stadia or bearing errors as the incorrect spot height is usually displaced a long way from the spots immediately before and after it. Such errors are quickly identified on the tabulation of field readings (Figure 11) as a warning message is given both before and after the incorrect reading.

- Where bearings are zero or negative.

- Where both stadia hairs are zero or negative.

- Where the axial hair is zero or negative.

- Where bearings and vertical angles exceed 360°.

- Where minutes and/or seconds exceed 60.

- Where the axial hair is not in the centre of the stadia hairs. (Distance is calculated using only the stadia hairs if both are recorded).

- Where the horizontal and vertical closes are excessive.

- Where a non-contour reading (N) does not have an associated landmark character.

- Where the second two readings onto the change points (backsights) are not consecutive.

- Where characters other than "1" or "2" are recorded in the CP column.

- Where the difference in level and/or horizontal distance between the two change points before and after the change of instrument position is excessive.

The "stage 2" computer plan (Figure 13) is useful for identifying errors as it shows the travel path of the staffman. If there are unexpected gaps in the profiles or sudden unexpected changes in direction of the profiles then there is probably an error at that point. Using the stage 1 computer plan (Figure 12) the incorrect spot height can be identified and the error traced back to the tabulated printout (Figure 11) using the X, Y co-ordinates on the plan.

If an error occurs at a change point in a theodolite survey some considerable care must be taken when making corrections. Any change to stadia distance measurements may result in a change in level of the instrument or the change point. Both these effects must be accounted for in the corrections.

When it is necessary to have data modified and the survey re-processed, the tabulated printout (Figure 11) only showing the corrections, needs to be returned for re-processing. Corrections made to handwritten field data can be confusing. The computer plans (figures 12, 13 and 14) are unnecessary so they need not be returned when data corrections are to be made.

14.0 EXAMPLE

The following figures give an example of CONTOUR'S printed output.

SURVEYING EXAMPLE 9/5/80 JONES CHRISTCHURCH

PLAN SCALE * * 2000.00 CONTOUR INTERVAL * * 0.50 052780 0.1 0.1

SEARCH RADIUS 50.000 METRES PROCESSING STAGE 3

BENCH MARK RL * * 169.540 SEARCH PASSES 0

ANGLE CORRECTIONS * * 0.00 VERTICAL AND 0.00 HORIZONTAL

INITIAL INSTRUMENT CO-ORDINATES, X = 0.000 Y = 0.000

X Y Z COORDINATES STORED ON DISK FILE XYZDATA INDEX= 10

			BEARING			VERTICAL															
AH	SH	SH	DEG	M	S	DEG	M	S	C	F	S	SEQ	REMARKS		RL	DIST	X	Y			PFILE
INITIAL INSTRUMENT HEIGHT = 170.540																					
1.000	1.950	0.050	203	40	0	0	0	0			N	0	BM1	1	169.540	190.000	-174.020	76.269		A	0.000
1.500	2.240	0.760	134	0	0	0	0	0	1		N	0			169.040	148.000	-102.809	-106.462		C	0.000
2.350	3.390	1.310	87	0	0	0	0	0	2		N	0			168.190	208.000	10.887	-207.715		C	0.000
2.000	2.630	1.370	64	0	0	0	0	0	2		N	0			168.190	126.000	0.000	0.000	**	I	
NEW INSTRUMENT HEIGHT = 170.190																					
1.150	1.950	0.350	0	40	0	0	0	0	1		N	0			169.040	160.000	-100.588	-266.447	**	I	
3.000	1.020	0.000	343	0	0	0	0	0		F		0			167.190	396.000	-225.999	109.170		,F	0.000
3.400	1.400	0.000	345	0	0	0	0	0				0			166.790	400.000	-213.948	117.154		3	14.456
3.080	1.150	0.000	348	0	0	0	0	0				0			167.110	386.000	-190.457	108.946		,	24.884
3.370	1.480	0.000	355	0	0	0	0	0				0			166.820	378.000	-143.137	109.151		3	47.320
3.760	1.900	0.000	358	0	0	0	0	0		F		0			166.430	372.000	-123.059	104.874		-F	20.528
2.670	0.830	0.000	6	0	0	0	0	0				0			167.520	368.000	-71.475	100.400		1	51.778
2.970	1.110	0.000	13	0	0	0	0	0				0			167.220	372.000	-26.184	98.037		.	45.352
3.080	1.140	0.000	22	0	0	0	0	0		F		0			167.110	388.000	35.531	96.893		.F	61.725
2.930	1.260	0.000	26	0	0	0	0	0				0			167.260	334.000	38.119	37.390		.	59.560
2.720	1.310	0.000	33	0	0	0	0	0				0			167.470	282.000	46.914	-26.099		.	64.095
1.960	0.740	0.000	42	0	0	0	0	0				0			168.230	244.000	57.999	-81.011		+	56.020
1.320	2.470	0.000	47	0	0	0	0	0		F		0			168.870	230.000	63.565	-105.345		2F	24.962
1.540	0.520	0.000	63	0	0	0	0	0				0			168.650	204.000	78.755	-169.224		2	65.660
1.360	0.380	0.000	77	0	0	0	0	0		F		0			168.830	196.000	89.201	-217.496		2F	49.390
0.950	1.810	0.000	101	0	0	0	0	0				0			169.240	172.000	69.035	-294.943		-	80.029
0.860	1.780	0.000	122	0	0	0	0	0				0			169.330	184.000	57.892	-359.935		-	65.940
1.070	2.110	0.000	132	0	0	0	0	0		F		0			169.120	208.000	57.490	-401.633		-F	41.700
0.540	1.520	0.000	133	0	0	0	0	0				0			169.650	196.000	46.124	-396.414		3	12.507
0.850	1.790	0.000	136	0	0	0	0	0				0			169.340	188.000	33.419	-398.303		-	12.845
0.370	1.230	0.000	141	0	0	0	0	0				0		2	169.820	172.000	11.034	-397.308		3	22.408
1.050	0.360	0.000	157	0	0	0	0	0		F		0			169.140	138.000	-43.440	-392.058		-F	54.726
0.840	1.460	0.000	174	0	0	0	0	0				0			169.350	124.000	-84.481	-389.396		-	41.127
1.330	0.670	0.000	208	0	0	0	0	0		F		0			168.860	132.000	-159.562	-384.540		2F	75.237
1.220	1.950	0.000	220	0	0	0	0	0				0			168.970	146.000	-191.548	-380.649		2	32.222
1.820	1.020	0.000	227	0	0	0	0	0		F		0			168.370	160.000	-214.780	-378.519		+F	23.329
1.870	1.250	0.000	251	0	0	0	0	0				0			168.320	124.000	-216.763	-309.798		+	68.750
2.360	1.720	0.000	292	0	0	0	0	0		F		0			167.830	128.000	-220.453	-221.543		1F	88.332
2.450	1.660	0.000	312	0	0	0	0	0				0			167.740	158.000	-220.666	-163.757		1	57.787
1.750	0.900	0.000	320	0	0	0	0	0		S	D	0	STONES		168.440	170.000	-213.151	-139.052		S	0.000
2.800	1.780	0.000	325	0	0	0	0	0				0			167.390	204.000	-221.826	-102.382		.	61.386
3.020	1.720	0.000	333	0	0	0	0	0		F		0			167.170	260.000	-224.502	-37.875		,F	64.563
3.330	1.900	0.000	336	0	0	0	0	0				0			166.860	286.000	-223.548	-8.228		3	29.662
2.970	1.280	0.000	340	0	0	0	0	0				0			167.220	338.000	-224.263	48.114		.	56.347
3.040	1.150	0.000	342	0	0	0	0	0			$	0			167.150	378.000	-226.538	89.953		.	41.901
3.000	1.400	0.000	347	0	0	0	0	0				0			167.190	320.000	-180.510	43.412		.	0.000
2.610	1.340	0.000	337	0	0	0	0	0				0			167.580	254.000	-205.771	-35.249		1	82.618

Figure 11. Tabulated Field Data

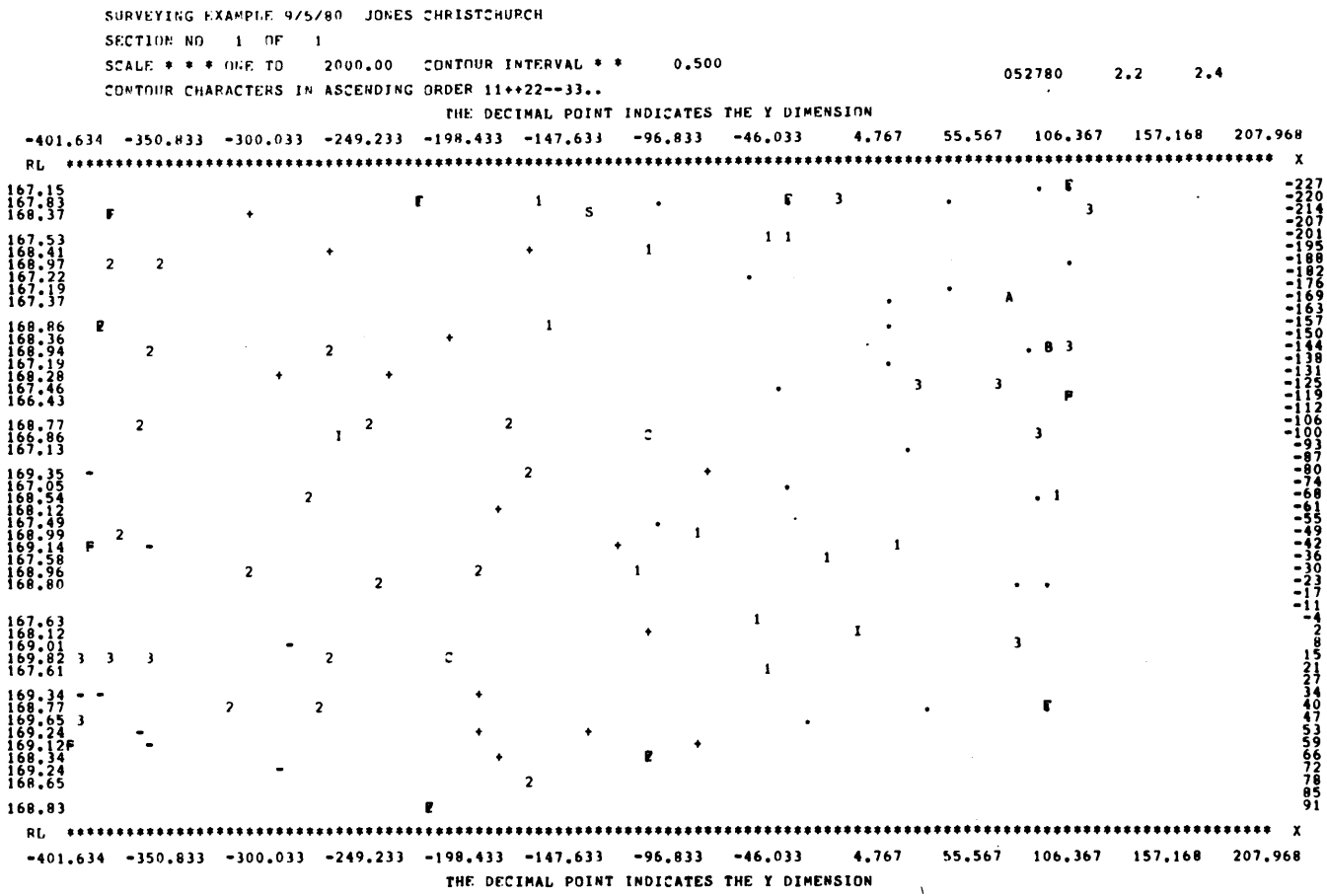

Figure 12. Stage One Plan

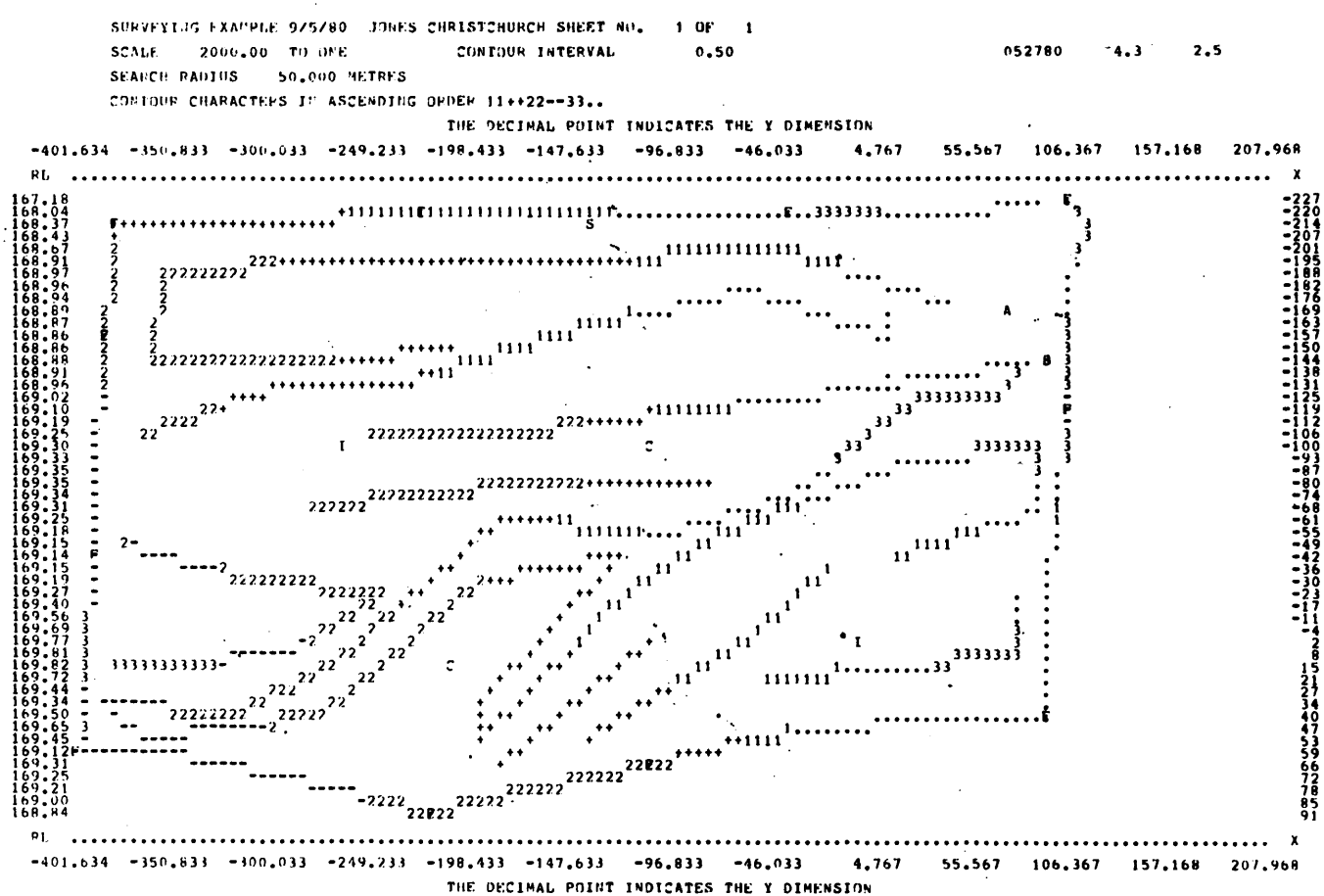

Figure 13. Stage Two Plan

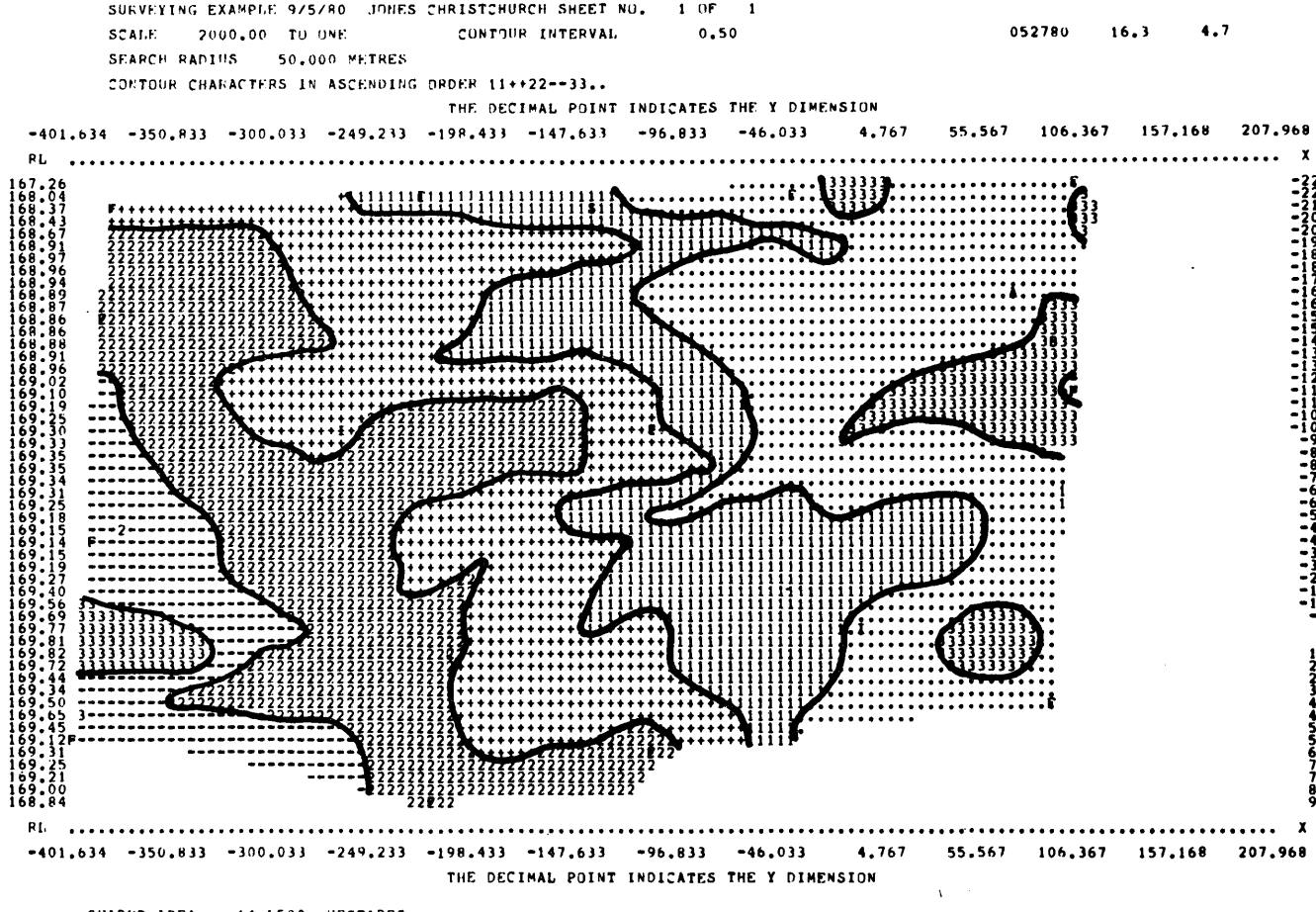

Figure 14. Stage Three Plan

15.0 INTERPRETING COMPUTER PRINTOUT

The tabulation of each field reading on the left hand side of the computer page is accompanied by the processed data from that reading on the right hand side of the computer page. (See Figure 11). The processed data is as follows:

- Reduced level (RL)

- Stadia distance (DIST)

- X-Y co-ordinates (X Y)
  These co-ordinates refer to the position of the spot height on the computer plan.

- Contour and/or landmark character.
  This character will be found on the computer plan in the X-Y position above. This can most easily be found initially on the plan of individual spot heights i.e. Stage 1. (See Figure 12).

- Profile distance (PFILE).
  This is the distance between profile points. If the previous spot height was a non-contour spot height then the profile distance will be zero.

The page numbers recorded on the booking sheets will appear in the REMARKS column on the computer printout. This helps to cross-reference from the computer printout to the booking sheets in order to identify any suspected punching errors.

The computer plans consist of a scatter of printer characters. The Y axis is across the top and bottom of the page and X axis is down the right hand side of the page. The position of any spot height can be identified by using this X, Y co-ordinate system. The initial instrument position is X=0, Y=0.

This method of printout which is convenient and rapid does not allow the reduced levels of all spot heights to be shown on the plan. In order to show as many of the reduced levels as possible, the reduced level of the left-most character on each computer printout line is printed down the left hand side of the plans. (As a separate operation, a computer plot can be made of all the reduced levels. This is, however, not usually necessary. See Figure 15).

Spot heights are displayed using the character code 11++22--33..11++. A contour line exists where the characters change. For example a contour line exists between the "1" and the "+" characters.

The character code 11++22--33..11++ etc., is in ascending order so that areas shaded in "+" characters are higher than areas shaded in "1" characters. Similarly "3" characters are higher than "-" characters. By stepping across the plan in this way the height of any of the contour lines can be found.
(Like the plot of reduced levels, a labelled computer contour plot can be produced as a separate operation. This is generally unnecessary also. See Figure 16).

16.0 ADDITIONAL FEATURES

The instructions in the first fifteen sections of this handbook should be sufficient for the majority of applications. There are, however, some features of CONTCUR which can extend the usefulness and versatility of the programme. They are included here so as not to cloud the more routine program operation instructions.

16.1 Additional Processing Stages

In addition to the stages mentioned in section 11 the stages -1 and 4 may be specified.

If stage -1 is specified (in columns 68 and 69) the processing is limited to the tabulated field readings. This is the stage automatically reverted to in the event of a serious data error.

If stage 4 is specified (or any number greater than 3) then the tabulated readings and the final contour plan only are printed.

16.2 Presentation of Data

To aid the speed and ease of punching data and to reduce punching errors it is recommended that the field levels in the booking sheets be recorded as consistently as possible. For example; if millimetres are to be read on staff readings then, within reason, all staff readings should show data in this column. Similarly, bearings expressed in minutes should also be consistent if they are to be used. This recommendation can be waived for change points where particular attention should be paid to accuracy.

16.3 Both Stadia Readings Set at Zero

If both stadia hairs are left blank or recorded as zero then the spot is assumed to be an error and the reading is changed to a non-contour spot height. The stadia distance is reduced to zero.

16.4 Spot Readings off the Plan

Where it is desired to take a single reading which may be well outside the surveyed area this may be recorded without increasing the processing time of the survey by specifying an "N option" and leaving the F column blank. Alternatively the axial hair only is recorded in the usual column and the stadia information recorded in the REMARKS area. The spot height can then be manually placed on the plan at some later time. These techniques cannot be used for the first and last readings in a survey or for change points as landmark characters are automatically printed in these cases.

16.5 Data Card Sequencing

As mentioned in Section 12; the booking sheet provides for the sequencing of all data cards. In the event of a calamity when the cards get out of order they could thereby be re-ordered correctly. Should the sequence number of the first card be greater than zero the programme will check that all sequence numbers are in order.

It has been found that the extra punching has not been warranted and that any errors detected have been because the sequence numbers were incorrect.

16.6 Excessive Separation of spot heights

It is stated in Section 5 that a profile segment may not be constructed by the programme if it is longer than specified in Figure 4. The reason for this is as follows. The programme CONTOUR processes a sub-area of the plan at a time. These are the width of the computer page and 64 rows down the page in size.

Around the outside of this sub-area is an overlap area. Any spot height or profile information in this overlap area may be used in determining the positions of contours in the actual sub-area being processed. Any data beyond the outer edge of the overlap area is ignored. If a profile begins on one strip of computer paper and travels across to another strip of paper in one step which exceeds the overlap distance, then the second spot height is not found by CONTOUR and the profile cannot be constructed. This is also true of processing sub-areas within one strip. Increasing the size of the memory overlap would decrease the chance of this happening but would increase the data processing time. At its present level, the overlap causes few problems.

On the very odd occasion when an important profile is discontinued by one of the causes mentioned above, an intermediate reading could be inserted by the surveyor in the middle of the profile before the survey data is reprocessed. Up to now, this has not been necessary.

16.7 Sudden Changes in Profile Direction

Changes in profile direction of more than 135° in one step should be avoided for important profiles. This may result in the segment of the profile immediately following the change of direction being discontinued. Because of the incremental nature of the computer profiles, a sudden change in direction of this

size can cause the profile to step back along the previous profile for a few character positions. This is not allowed by the programme and hence the segment of the profile following the direction change is not generated.

These sudden changes in direction have yet to cause any practical difficulty because they seldom occur and if they do then that length of profile may not be vital.

16.8 Search Radius and Profile Separation

In order to generate the line printer display of contours, all the line printer character positions must be assigned a spot height. Any position which is not already recorded as a field spot height or a profile must be interpolated from the existing field information. This is done by searching outward from the position of the unknown spot height and finding the first recorded spot height in each of the eight sectors surrounding the unknown spot height. The further outward the search continues, the greater the processing time and hence cost of running CONTOUR. A limit is put on this search distance and this is called the search radius. A weighted average of the data found in this search procedure is used to approximate the unknown spot heights.

If, within the search radius, no recorded spot height information is found in any four consecutive sectors the spot height is assigned the value zero. No contour data is printed in such positions and hence the boundary of the surveyed area is determined. If the profile separation is greater than the specified search radius the area between the profiles will not be contoured.

16.9 Changing the Plan Orientation and Registration

Additional input data may be entered on the first two header cards of any survey to change the output orientation, registration and form. These are not included on the ordinary booking sheets to avoid confusion. These data may be added later by the person processing the survey.

- ANGLE may be specified in columns 70 to 80, of the first header card. Thids will orientate the plan anti-clockwise by the number of degrees specified (e.g. 12.5)

- EX may be specified in columns 20 to 26 of the second header card. This will set the initial instrument position at the X value specified (e.g. 145.8)

- WY may be specified in columns 27 to 33 of the second header card. This will set the initial instrument position at the Y value specified (e.g. 99.4)

- NSR (Integer) may be specified in columns 67 to 69 of the second header card. The value entered here will restrict the number of search passes to that specified value. This has the effect of reducing the processing time but also reduces the definition of the contour plan. A typical value to specify would be 6 (See Section 16.13).

- VCIRC may be specified in columns 70 to 76 of the second header card. This is used to vary vertical circle readings. If a theodolite has horizontal readings of 0^{o} and 180^{o} then VCIRC may be set at -90.0 which will allow the vertical circle readings to be processed by CONTOUR.

16.10 Verifying Field Data

The normal data processing procedure of verifying data cards or disk files may be waived using CONTOUR provided that the data entry operators are very experienced and accurate. The data checks within the programme provide considerable security against producing unwanted excessive printout or excessive processing time should there by a few punching errors.

16.11 Port-a-Punch Cards

It is possible to use these 40 column manually punched cards for data input. (The cards are actually 80 column cards with the odd numbered columns not available). This can take two forms:-

(a) The first two cards as normal cards and the rest port-a-punch cards. The port-a-punch cards are indicated by 1 in column 1 of card two in this case.

(b) All port-a-punch cards can be used. In this case the title only is punched on the first card. The benchmark height, scale, and search radius are punched on the second card as follows:-
BM - decimal point assumed on column 9.
SCALE - decimal point assumed on column 19.
RADIUS- decimal point assumed on column 31.
SCALE - column 32.
CONTOUR INTERVAL - decimal point assumed on column 37.

In each case the field readings are booked as follows:
AXIAL HAIR - decimal point assumed on column 5.
STADIA HAIR - decimal point assumed on column 15.
STADIA HAIR - decimal point assumed on column 25.
BEARINGS DEG " " " " " 37.

	MIN	"	"	"	"	" 41.
	SEC	"	"	"	"	" 45.
VERTICAL	DEG	"	"	"	"	" 51.
	MIN	"	"	"	"	" 55.
	SEC	"	"	"	"	" 59.
CP	Recorded in column 60.					
F	Recorded in column 62.					
$	"	"	"	64.		
REMARK	"	"	"	66 to 72.		

Landmarks (F) are coded as follows:

0 - blank
1 - F
2 - G
3 - H
4 - J
5 - K
6 - L
7 - M
8 - N
9 - O

$ Characters are coded as follows:

0 - blank
1 - $
2 - N
3 - D

All remarks are in numeric code as punched and must be encoded and interpreted by the surveyor.

The use of Port-a-Punch cards has not found great favour because they are slightly unwieldy in the field and difficult to rapidly read. Furthermore they are much more expensive than

ordinary cards. They could, however, be used in situations where card punching services were not available. They have the advantage of immediate processing of the survey data without waiting for the punching operation.

16.12 Permanent Data Files

CCNTOUR can be used to generate two different data files which remain in computer disk memory. These files can be used independently by other computer programmes as required.

(a) XYZDATA. This file is generated if any integer number is specified in columns 17 to 19 of the second header card. This file will be generated as long as all the data is processed to at least stage -1.

The file structure is as follows: (6 words per record)

Record 1:-

IDIR - The last record number which contains data
YIN - minimum Y dimension
YAX - maximum Y dimension
XIN - minimum X dimension
XAX - maximum X dimension
Last - reserved

Records 2 to IDIR:-

X - X co-ordinate
Y - Y co-ordinate
$ - $ option
F - landmark character
RL - Reduced level
Last - Reserved

Records IDIR + 1 and IDIR + 2
Words 1 to 5 are the survey title in A4 format.

(b) DTMDATA. This file is generated if any integer number is specified in columns 2 to 5 of the second header card. This file is generated only if CONTOUR is run to at least stage 3. This digital terrain model contains the spot height of all the character positions in the line printer contour plan.

The file structure is as follows: (one word per record)

Records 1 to 11		Survey title in A4 format
Record	21	Number of rows (I format)
	22	Number of columns (I format)
	23	Printer row spacing (inches) in F format
	24	Printer column spacing (inches) in F format
	25	Contour interval (metres) in F format
	26	Scaled column spacing (metres)
	27	Scaled row spacing (metres)
Records	101	and onwards are used to store the spot heights according to the formula below.

Record No. = 100 + (NNR-1)* NTC+NNC

Where NNR = Row number (greater than zero)
NNC = Column number (greater than zero)
NTC = Total number of columns.

16.13 Further Information on CONTOUR

Further information on the development of CONTOUR is available in Reference 1.

17.0 LINE PLOTTER DISPLAYS

Using a line plotter as distinct from line printer, a higher quality presentation is possible. It is not always necessary to have this standard of presentation; it is slower to produce and is an additional operation following the line printer operation.

17.1 Spot Height Display

Using the XYZDATA file described in Section 16.12, the Fortran programme SPOTPLOT will produce a line plotter display of all the spot heights and landmark characters recorded in the field survey. These can be shown on a plan at any specified scale. (See Figure 15).

17.2 Contour display

Using the DTMDATA file described in Section 16.12, the Fortran programme LINECONTOUR will produce line plotter contours to any specified scale and contour interval. The contours may be labelled if desired. (See Figure 16).

17.3 Three-dimensional Display

Using the DTMDATA file described in Section 16.12 the programme C3D can be used to produce a three-dimensional display of the terrain on a line plotter. Contours may also be fitted to this three-dimensional surface. (See Figure 17). This programme is described in Reference 2.

18.0 REFERENCES

1. HARRINGTON, G.J. 1976. "Contouring by computer from stadia field data". NZAEI project report P/13 Lincoln College, New Zealand.

2. HARRINGTON, G.J. 1978. "Three dimensional computer drawings for agricultural engineering". NZAEI project report P/17. Lincoln College, New Zealand

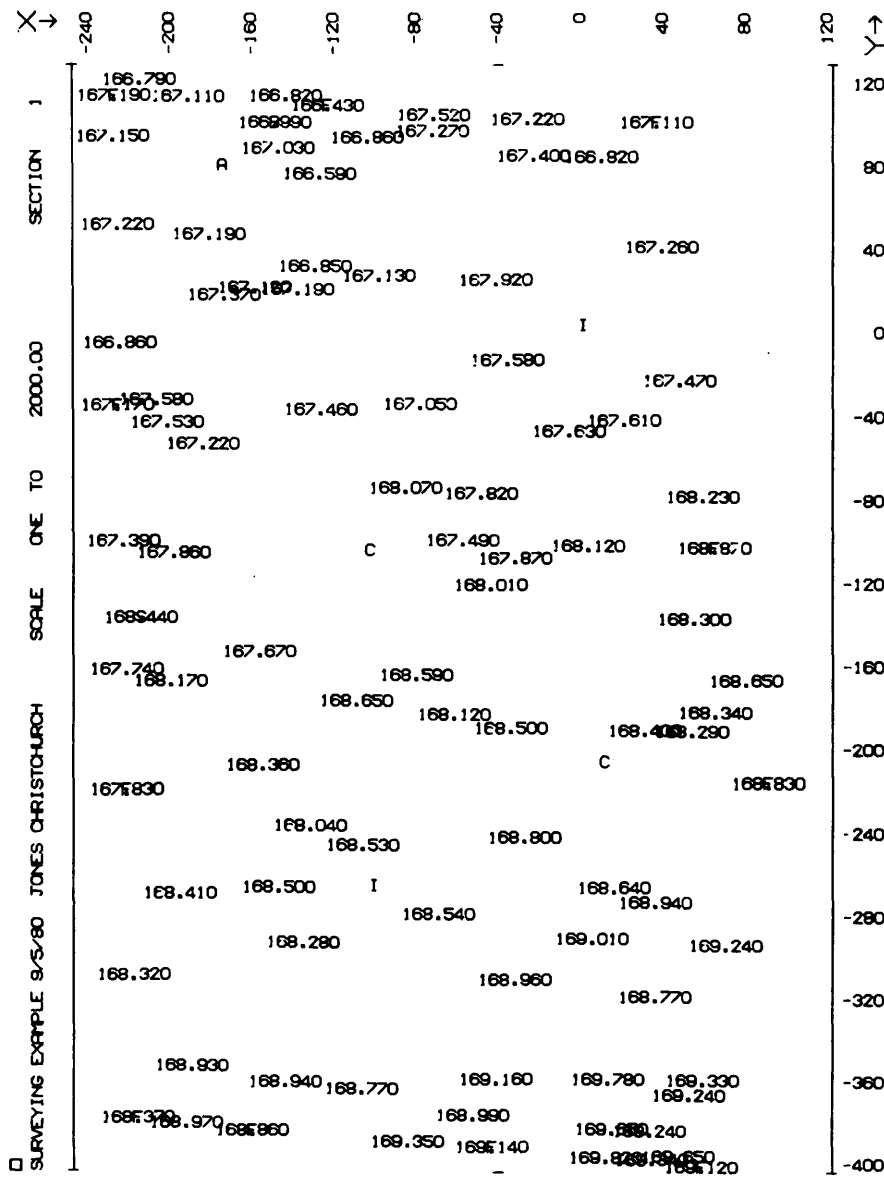

Figure 15. Plotter Spot Heights

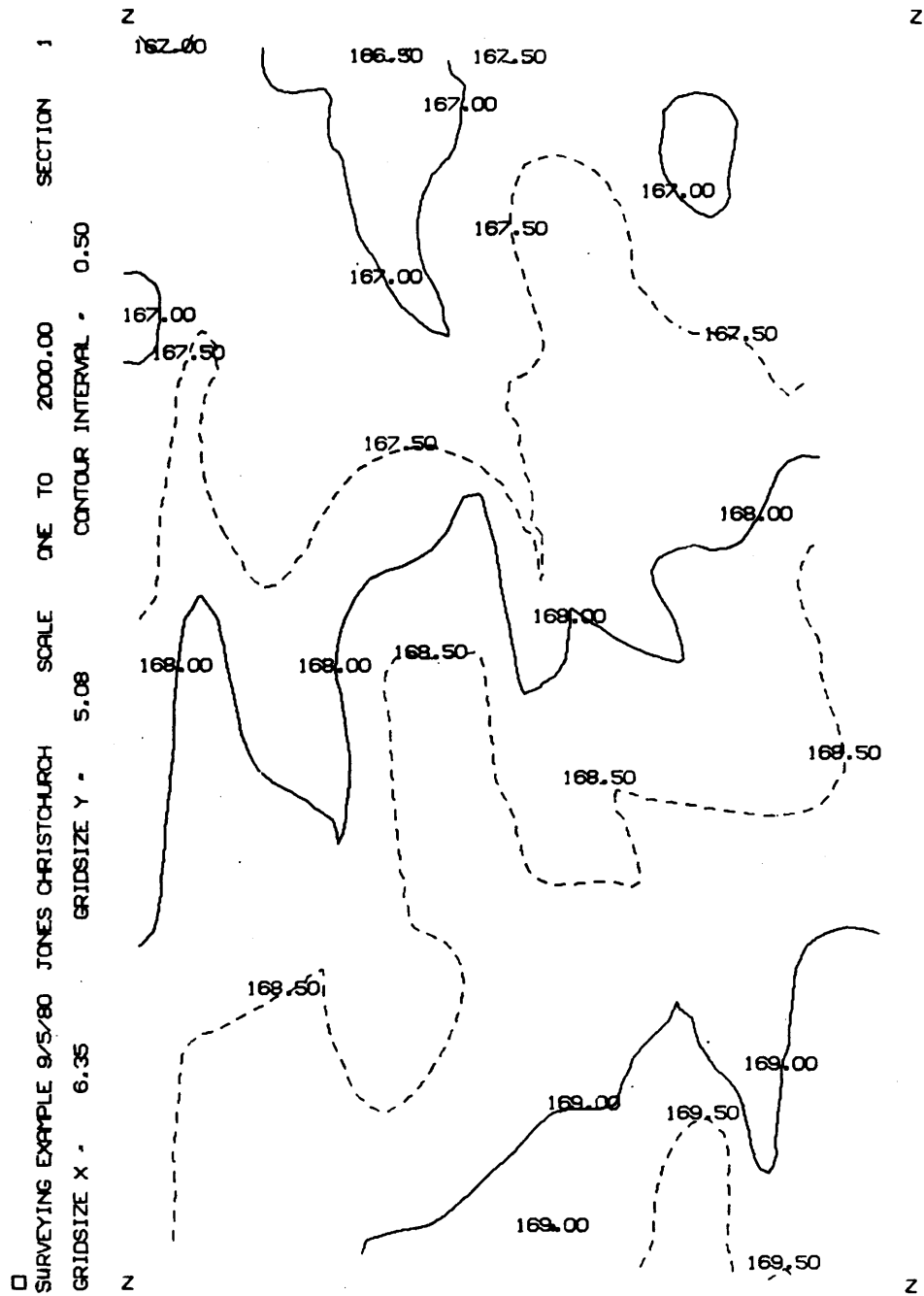

Figure 16. Plotter Contour Plan

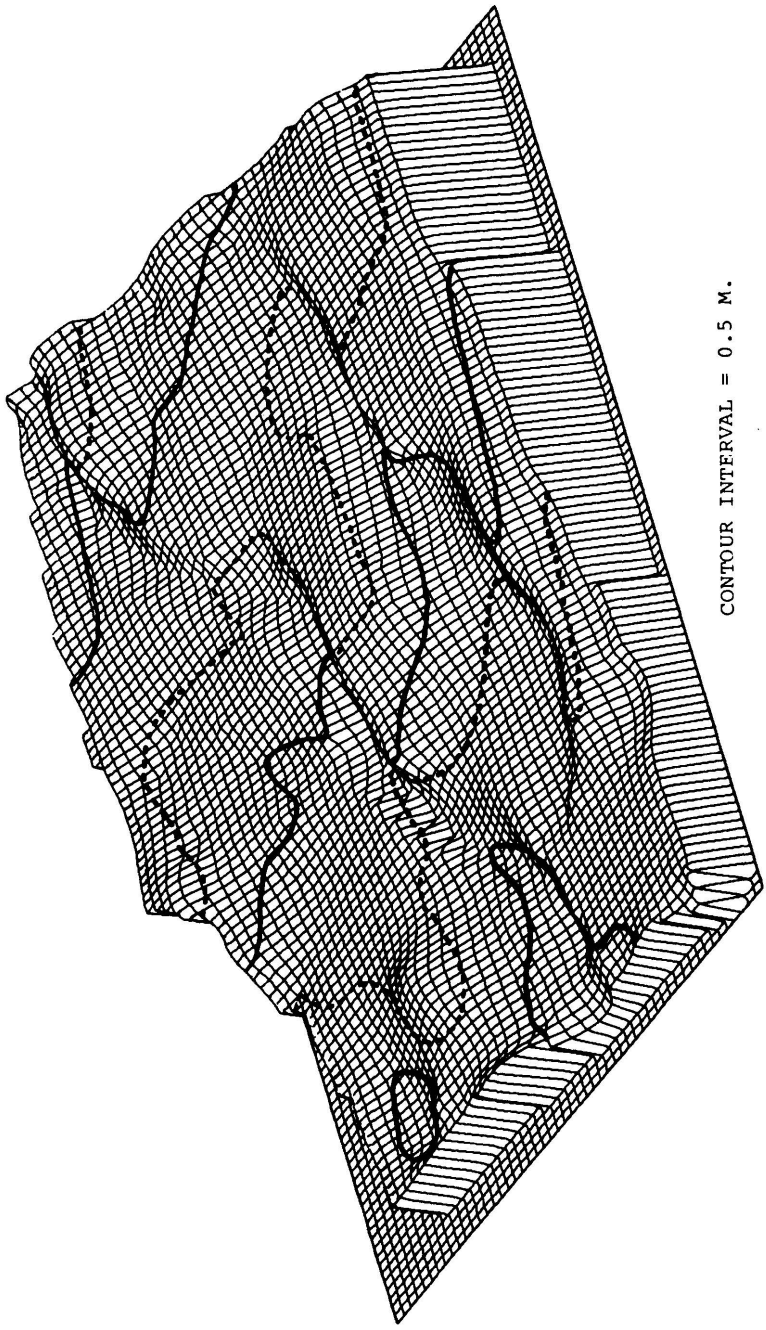

Figure 17. THREE-DIMENSIONAL DISPLAY