14th CONGRESS OF THE INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY
HAMBURG 1980
COMMISSION IV, WORKING GROUP I
INVITED PAPER

ACCURACY AND TIME COMPARISONS OF DIGITAL MAPS - AN INTERNATIONAL TEST

by

Dr. Salem E. Masry*
Jean R.R. Gauthier*
Y.C. Lee*

ABSTRACT

An international experiment has been conducted to provide answers related to two important aspects of digital mapping:

(a) the accuracy of digital data and their suitability for mapping at larger scales, and

(b) the time requirements for data collection.

One test area (180 km^2) was covered by photography at scales 1:50 000 and 1:15 000 and a second area (3km^2) was covered by photography at scales 1:6000 and 1:3000. The small scale photography of the two areas (1:50 000 and 1:6000) was used for digitization by the participants in the experiment. The large scales (1:15 000 and 1:3000) were used in collection of "standard" data against which the participants' results were tested. Software was developed to carry out the tests digitally. Two different algorithms were used to evaluate both the height and the planimetric accuracy. The paper includes a description of the algorithms, a summary of the accuracy results and a time comparison of the different operations as reported by the participants.

RESUME

Les résultats de deux tests internationaux sur la précision des données numériques à grande et à petite échelles et les temps d'acquisition de ces données font l'objet de la présente communication. Pour ces deux tests, on procéda à la photographie aérienne de deux zones:

- une zone de 180 km^2 avec prise de vue à 1:50 000 et 1:15 000 pour le test à petite échelle,

*First and third authors are with the Surveying Engineering Department, University of New Brunswick, Fredericton, N.B.; and second author is with Topographical Survey, Surveys and Mapping Branch, 615 Booth St. Ottawa, Ontario, Canada.

(b) une zone de 3 km^2 avec prise de vues à 1:6000 et 1:3000 pour le test à grande échelle.

Pour l'acquisition des données, les participants au test à petite échelle reçurent les photographies à 1:50 000; ceux désirant prendre part au test à grande échelle utilisèrent les photographies à 1:6000. Les photographies aux 1:15 000 et 1:3000 servirent à la numérisation des données de contrôle.

Les résultats de chaque participant furent comparés numériquement aux données de contrôle à l'aide d'un logiciel réalisé pour cette fin et basé sur deux algorithmes différents pour chaque test planimétrique et altimétrique. On décrit ces algorithmes ainsi que les résultats obtenus par les participants.

ZUSAMMENFASSUNG

Ein internationales Experiment wurde durchgeführt zur Beantwortung von Fragen mit zwei eng verbundenen Aspekten;

(a) Genauigkeit von digitalen Daten und ihre Eignung für grosse Masstäbe und,

(b) Zeit notwendig zur Daten Ansammlung.

Ein Tesfeld von 180 km^2 wurde photographiert, Masstab 1:50 000 und 1:15 000 und ein weiteres Testfeld von 3 km^2 Masstab 1:6000 and 1:3000. Die Kleinmasstäbliche Photographie wurde von den Teilnehmern an dem Experiment digitiert. Die grossmasstäbliche Photographie (1:15 000 and 1:3000) wurde zur Auswertung von Kontrolldaten gebraucht, gegen die, die Daten der Teilnehmer geprüft wurden. Ein Programmierverfahren zum Vergleichen der digitalen Daten wurde entwickelt. Zwei verschiedene Algorithmen wurden zur Bestimmung der höhen und planimetrische Genauigkeit angewandt. Die algorithmen, Genauigkeitsresultate sowie Zwitvergleiche der verschiedenen Arbeitsverfahren werden diskutiert.

INTRODUCTION

Utilization of digital data for the production of maps at different scales involves two main considerations:

(1) The amount of detail: Obviously the amount of information needed to produce large scale maps of a certain area is greater than that required to produce a small scale map of the same area. This may impose a limit on the largest scale which can be produced from a given set of data. Conversely, generalization may be necessary in order to produce small scale maps from the same data set.

(2) The accuracy of digital data: The accuracy of digital data is normally preserved, as opposed to the usual degradation of accuracy in the case of the conventional production of graphical

maps. The accuracy is expected to be higher if the data is collected directly from stereomodels. It may, therefore, be possible to use the data for larger map scales than has been the practice with conventional mapping, and still meet adopted map accuracy standards, or carry out the mapping at smaller scales.

Traditionally, the map scale is rarely larger than four times the photo scale. If, however, it is shown that digital data are suitable for greater enlargements, then the information content may be increased in two ways:

(a) Collection of more detail at the digitization stage to the limit provided by the photography, and

(b) Addition of information from other sources (obviously, the use of digital data lends itself to this).

It is, therefore, important to evaluate the accuracy of digital data produced by different methods.

Another aspect of digital mapping for which there is not at present sufficient information is the time requirements of various methods such as interactive digitizing of stereomodels, digitizing of manuscripts, etc.

An international test was, therefore, organized by Working Group 1, Commission IV of ISP with the objective of providing answers to the questions of accuracy and time requirements.

This paper deals with description of the test and collection of "standard" data used in the accuracy tests. This is followed by description of algorithms and procedure for accuracy tests and an analysis of the results obtained. Conclusions and suggestions for future tests are then given. Computer requirements of algorithms, sample questionnaire provided to participants, etc. are included in appendices to the paper.

DESCRIPTION OF THE TESTS

Test Areas and Scales

Two test areas were selected; one selected for evaluating relatively small scale mapping (1:50 000) and the other for larger scale mapping (1:6000). Each area was flown at two different scales, one used by the participants, and a larger scale used as a "standard" against which all the participant's data were compared.

The small scale test area is situated to the west of Ottawa and covers an area of about 180 km^2. It was photographed at the scales 1:50 000 and 1:15 000. The large scale test area is east of Ottawa and covered an area of 3 km^2. It was photographed at 1:6000 and 1:3000 scales. Selected details from 1:50 000 and 1:6000 photographs (4 stereo models) were digitized by the participants. The same details were digitized using the 1:15 000 and 1:3000 photographs respectively. These data were then used as "standard" against which the participant's data were compared. More detail about the generation of the "standard" data is given below.

Ground Control

In order to ensure the validity of the accuracy comparison, a great deal of thought was given to the two following questions:

(1) how to ensure that the control used for the two sets of photographs of each area be fully integrated.

(2) how to make sure that each participant receives diapositives with identical control points.

To satisfy the first requirement, it was decided to do a simultaneous adjustment of both the high and low level photography for each test area.

As an answer to the second question, two methods were considered:

(a) pre-targetting all necessary tie-points,

(b) marking the negatives before producing the diapositives to be sent to the participants.

Method (b) was investigated and found to be satisfactory. However, it was at first rejected to avoid possible interference with automatic correlation equipment. Later on, difficulties in obtaining photographs with all the necessary targetted control forced us to fall back on this method for the large scale test. In turn, this led to a most unfortunate mistake which affected the photographs of the large scale test and which is explained later.

Aerotriangulation measurements for both the small and the large scale tests were carried out on a Wild A-10 and two Wild STK-1 stereocomparators. Program PAT-M was used to adjust simultaneously the independent models for the two levels of photography, that is:

- for the small scale test the single strip of 1:50 000 scale photography was combined with the three strips of 1:15 000 scale photography,

- similarly, for the large scale test, the single strip of 1:6000 scale photography was adjusted with the two strips of 1:3000 scale photography.

Statistics for these two adjustments are as follows:

- small scale test

(horizontal)	=	0.750 m or 15 µm	at photo scale
(vertical)	=	0.541 m or 11 µm	at photo scale

- large scale test

(horizontal)	=	0.055 m or 9 µm	at photo scale
(vertical)	=	0.075 m or 12 µm	at photo scale

Despite the precautions taken to ensure that each participant received diapositives with identical control, a blunder was made in preparing the participants' diapositives for the large scale test. In brief, the accident occured when, unknown to the organizers, a set of unmarked diapositives was marked and aerotriangulation was carried out with good results. The pass points were then transferred to the negatives and the participants' diapositives produced! Naturally, unacceptable errors occured during this transfer. To make matters worse, the organizers carried out the test with the original diapositives and thus did not detect the errors.

In an attempt to correct this regrettable situation, it was decided to provide each participant with new, correct values for their control points and to ask them to repeat the large scale test. Quite understandably some of them declined.

Test Material Provided to Participants

The test material provided to participants consisted of:

(a) a map of the area showing precisely the planimetric detail and contours to be digitized. Only unobscured, well defined detail was selected.

(b) one set of diapositives for each test area with control points marked and numbered;

(c) coordinates of control points;

(d) specifications of the final format of the digital data which were to be provided by a participant on magnetic tape.

To evaluate the time requirements of digital mapping, each participant was provided with a questionnaire. The questions were designed so as to overcome variations in salaries, exchange rates, import duties etc. and still be able to compare the efficiency of the mthods used by the participants.

PARTICIPANTS IN THE TESTS

A total of 8 organizations participated in the small scale test and 15 participated in the large scale test. Their name and addresses are listed below. The authors take this opportunity gratefully to acknowledge their effort and contribution which made the test possible.

Participants in the Small Scale Test

Name of Organization	Address	Name of Contact
Div. of National Mapping Dept. of National Development	P.O. Box 548, Queanbeyan, Australia	Dr. S.L. Kirkby Assistant Director, Topography, Div. of National Mapping P.O. Box 608 Dandenong, Vic 3175 Australia

Participants in the Small Scale Test (Con't)

Name of Organization	Address	Name of Contact
Fairey Surveys Ltd.	Reform Road Maidenhead Berkshire, SL6 8BU England	Mr. O.W. Cheffins
Hunting Surveys Ltd.	Elstree Way Borehamwood Herts, WD6 1SB England	Mr. J.D. Leatherdale
Nakaniwa Survey Co. Ltd.	No. 3-14, 2-chome Ebisu-minami Shubuya-ku Tokyo, Japan	Prof. Chuji Mori Dept. of Civil Eng. School of Engineering Okayama University Tsushima-naka 3 Okayama, Japan 700
Pacific Aero Survey Co. Ltd.	13-5, 2-chome Higashiyama Meguro-ku, Tokyo Japan 153	Prof. Chuji Mori (see Nakaniwa)
Topographical Survey Dept. of Energy, Mines and Resources	615 Booth St. Ottawa, K1A 0E9 Canada	Mr. J.G. Gibbons
U.S. Geological Survey Topographic Division	U.S. Geological Survey National Center, MS519 12201 Sunrise Valley Dr. Reston, Virginia 22092 U.S.A.	Mr. R.R. Mullen
University of New Brunswick Dept. of Surveying Engineering	P.O. Box 4400 Fredericton, N.B. E3B 5A3 Canada	Prof. E.E. Derenyi

Participants in the Large Scale Test

Name of Organization	Address	Name of Contact
Asia Air Survey Co. Ltd.	2-16, 5-chome, Tsurumaki Setagaya-ku, Tokyo Japan 154	Prof. Chuji Mori (see Ohba)
Delft University of Technology Dept. of Geodesy	T.H. Delft Thijsseweg 11 Delft The Netherlands	Dr. G.H. Ligterink

Participants in the Large Scale Test (Con't)

Name of Organization	Address	Name of Contact
Fairey Surveys Ltd.	Reform Road Maidenhead Berkshire, SL6 8BU England	Mr. O.W. Cheffins
Geodetski Zavod SRS	61 000 Ljubljana Saranoviceva 12 Slovenija, Yugoslavia	Dr. Jure Besenicar
Geographical Survey Institute, Ministry of Construction	Kitazato-L, Yatabe-machi Isukuba-zun, Ibaraki-ken 300-21 Japan	Mr. Masanon Koide
Hunting Surveys Ltd.	Ellstree Way Borehamwood Herts, WD6 1S8 England	Mr. J.D. Leatherdale
International Institute for Aerial Surveys and Earth Sciences (ITC)	350 Boulevard 1945 Enschede The Netherlands	Dr. Ing. P. Stefanovic
Metro Aerial Survey Co. Ltd.	1-12 Yamanouchi-Chou Sumiyosi-ku, Osaka Japan	Prof. Chuji Mori (see Ohba)
Ministère de l'énergie et des ressources, Service de la Cartographie	1995, boul. Charest ouest Ste-Foy, Québec G1N 4H9 Canada	M. Jules Côté
Ohba Co., Ltd. Tokyo Branch	No. 4-12, 4-chome Aobadai Meguro-ku Tokyo, Japan	Prof. Chuji Mori Dept. of Civil Eng. School of Engineering Okayama University Tsushima-naka 3 Okayama, Japan 700
South Australian Highways Dept.	33 Warwick St. Walkerville S. Australia 5081 Australia	Mr. B.D. Spencer
Topographical Survey Dept. of Energy, Mines and Resources	615 Booth St. Ottawa, K1A 0E9 Canada	Mr. J.G. Gibbons
Toyo Aero Survey Co. Ltd.	3-1-1, Minami-dai Kowagoe-shi, Saitama Japan 350	Prof. Chuji Mori (see Ohba)

Participants to the Large Scale Test (Con't)

Name of Organization	Address	Name of Contact
U.S. Geological Topographic Division	U.S. Geological Survey National Center, MS 519 12201 Sunrise Valley Dr. Reston, Virginia, 22092 U.S.A.	Mr. R.R. Mullen
University of New Brunswick Dept. of Surveying Engineering	P.O. Box 4400 Fredericton, N.B. E3B 5A3 Canada	Prof. E.E. Derenyi

Some difficulties with the format of the data received and the problem with the control used in the large scale prevented processing some of the data received. A summary of the number of participants whose data were successfully processed is shown in Table 1.

	Small Scale		Large Scale	
	Planimetry	Height	Planimetry	Height
NO.	6	4	5	3

Table 1
Summary of Data Successfully Processed

Intentionally, there is no cross reference between the results presented here and the name of the participants.

COLLECTION OF STANDARD DATA

The larger scales (1:15 000 and 1:3000) were digitized by the Topographical Survey, Surveys and Mapping Branch, Ottawa, and used as the "standard" data. The digitization was performed on a new Wild AMH instrument. The instrument was calibrated before the digitization commenced. A summary of the calibration is as follows:

Root mean square error in height from grid stereo measurements at photo-scale: $\pm$ 8 μm

Root mean square in X and Y directions for right photo from mono measurements: $\pm$ 5 μm

Root mean square error in X and Y directions for left photo from mono-measurements: $\pm$ 4 μm

The digitization was carried out directly from the stereomodels and edited interactively using graphical CRT displays on-line with the digitization operation. The relief digitized consisted of only contours. Doubtful contours or parts of them were indicated on the map provided to the participants as dotted (such as parts of contours in wooded areas). Participants were asked to digitize these to improve the time comparison, but they were not used in the accuracy test.

The data collected were not generalized. Points on line features were recorded in time mode. Average spacing between points in these features and on contours is as indicated in Table 2.

Scale 1:3000		Small Scale 1:15 000	
Planimetry	Contours	Planimetry	Contours
1 m	1 m	6 m	5 m

Table 2
Average spacing between points describing sinuous features and contours in the "standard" data.

ALGORITHMS AND PROCEDURES USED IN ACCURACY TESTS

Evaluation of height and planimetric accuracy was carried out completely digitally. The algorithms are discussed in this section briefly. More discussion about the algorithms and their computer requirements can be found in Appendix 1.

Evaluation of Height Accuracy

The accuracy in height was evaluated using two algorithms; these are referred to here as:

(a) Maximum Gradient Algorithm, and

(b) Weighted Mean Interpolation Algorithm.

Each of these algorithms determines the height from a participant's data at selected points of the "standard" contours. The deviation in the participant's data is the difference between the "standard" contour height and the interpolated height at each of the selected points. It is realized that the deviation may be affected by some interpolation errors. Attempt was made to assess these and are discussed in the analysis of the results given below.

(a) Maximum Gradient Algorithm

The height at a point s (Fig. 1) is interpolated by determining the maximum terrain gradient through point s.

The shortest lines, from s to contours A and B (sa and sb in the figure) are assumed to approximate the maximum gradient of the terrain at s. The interpolated height h_s is given by:

$$h_s = h_A + (h_B - h_A) \cdot \frac{sa}{sb + sa} \qquad (1)$$

where h_A and h_B are the heights of contours A and B of the participant's data. The error's of the participant's data at s, e_s, is given by:

$$e_s = h_s - h_{A'} \qquad (2)$$

where $h_{A'}$ is the height of the "standard" contour A' of which s is a a point.

(b) Weighted Mean Interpolation Algorithm

The interpolated height at point s, computed using the Weighted Mean Interpolation Algorithm is given by:

$$h_s = \frac{\Sigma \frac{1}{d_i^2} h_i}{\Sigma \frac{1}{d_i^2}} \qquad (3)$$

where d_i is the distance between point s and a point i on a participant's contours A,B,C,D etc.; and h_i is the height of point i as given by the participants' contours. Similar to algorithm (a), the error at point s is computed using equation (2).

Procedure for Carrying out Height Accuracy Tests

The "standard" contours which were used in the accuracy tests were selected so that cases where extrapolation may take place were avoided. Two of such cases are as illustrated by Figures 2 and 3. This was done by removing these contours from the "standard" file using an interactive CRT display. Other cases where extrapolation took place and those which were not detected visualy were detected by the software and eliminated.

Not all the points of the "standard" contours were used in the accuracy tests. This was mainly to reduce the computer time requirements. Every sixth point was selected in the small scale test, and every fourth point was selected in the large scale test. As a result, the total number of check points used were 2580 and 4510 for the small and large scale tests respectively.

When the software was developed, a choice had to be made between optimization of the core requirements and input/output requirements. The former was selected. In this case, all of a participant's data were stored in core together with the reduced points of one "standard" contour.

Interpretation at each of these points was performed then another "standard" contour was brought into core, etc.

To reduce the search for points a and b (Fig. 1) and, consequently, reduce the computer time requirements, the error in height was assumed not to exceed 2I; where I is the contour interval. On this basis for any "standard" point s, the search was limited to 5 contour values of participant's data which have height H in the range:

$$h_{A'} - 2\,I \leqslant H \leqslant h_{A'} + 2\,I$$

The participant's contours with these values were "flagged" and used for interpolation of all points of $h_{A'}$. When processing of all points of $h_{A'}$ was completed and another standard contour was brought into core, another set of 5 contours was "flagged" and so one.

While searching for points a and b (Fig. 1), the shortest distance between s and each of the 5 contours was stored. These 5 values were used in the weighted Mean Interpolation Method.

Evaluation of Planimetric Accuracy

For the purpose of evaluating planimetric accuracy, features can be classified into two main categories:

(a) Distinct Point Features

Distinct point features are features such as towers, houses composed of distinct points. Such features are usually recorded by the point recording mode and allow a one to one correspondence between points of the "standard" data and a participant's data.

The deviation vector, e_v, between a standard point and a participant's point can be expressed as:

$$e_v = \sqrt{(X_p - X_s)^2 + (Y_p - Y_s)^2} \qquad (4)$$

where X_p, Y_p are the coordinates of the point tested from a participant's data and X_s, Y_s are the "standard" coordinates of the same point.

(b) Continuous Line Features

The term Continuous Line Feature or, in brief, Line Feature applies to features usually recorded in a continuous recording mode (time or distance).

The implication is that no one to one correspondence between the "standard" points and a participant's points of that feature can be easily determined. Some assumptions must, therefore, be made to evaluate the deviation of a participant's feature relative to the "standard" one. The evaluation was performed using two methods:

(1) The Area Method, and the
(2) Generated Points Method

(i) The Area Method

In this method the area bounded by the "standard" line and the corresponding participant's feature is calculated (Fig. 4). If the length of this feature is L, an average deviation between the the two is given by:

$$e_a = \frac{A}{L} \qquad (5)$$

where A is the bounded area over the length tested; and L is the length of the "standard" feature. Practically, the feature to be tested must be divided into segments. If C and D are the end points of a "standard" segment, the most logical approach is to assume that the deviation at C and D is in the direction of the normals to the "standard" feature at these points. Accordingly, the two end points C and D of a participant's feature are determined.

(ii) Generated Points Method

A "standard" segment CD and the corresponding participant's C'D' are selected as outlined in the Area Method. The "standard" segment is divided by a number of equally spaced points. The corresponding participant's segment is then divided by the same number of points. The jth point of CD (Fig. 5) is assumed to correspond to the jth point of C'D'. For the corresponding points J and J' in the figure, the deviation e_g is calculated as:

$$e_g = \sqrt{(X_J - X_{J'})^2 + (Y_J - Y_{J'})^2}$$

Procedure for Carrying Out Planimetric Accuracy Tests

As for the height tests, a set of planimetric feature was selected from the "standard" data to test each participant's data. In the case of distinct point features the "standard" data were displayed on a graphics CRT and points such as house corners, etc. were selected to form part of the standard set. Selection was such that the "standard" points very close to one another were excluded so as to avoid the error of making calculations between non-corresponding points. (The participant's point corresponding to a "standard" point must be the closest point whithin a specified circle).

In the case of line features the "standard" segments were also selected interactively using a window. The selection was such that parts of a feature with overlapping data points or gaps were excluded (see Fig. 6). The window size and shape adopted varied with the segment taken so that the two sides determining the ends of a segment were perpendicular to the directions of the segment at its end points. This is to take into consideration the derivation assumption discussed above. The coordinates of the points defining the window were stored with the selected segment for the subsequent retrieval of the corresponding segment from a participant's data.

Each "standard" segment was divided by a number of equally spaced points as discussed above. This number was stored with the "standard" segment. The spacing between points was about 2.5 m in the large scale test and 25 m in the small scale test.

A participant's segment within each of the chosen windows was then retrieved, divided into same number of equally spaced points and the accuracy test is performed using each of the algorithms given above. The area calculations were performed using a formula which utilizes the coordinates of points on the perimeter of a figure.

ANALYSIS OF HEIGHT RESULTS

The following parameters were computed for each of the Maximum Gradient and Weighted Mean Interpolation methods:

(1) Maximum absolute value of the error e_s

(2) Minimum absolute value of the error e_s

(3) Root Mean Square Error (R.M.S.).

A method which is usually followed in analyzing the height errors of a map is to express the root mean square error as a linear function of the slope, i.e. by Koppe's formula (Gustafson, 1977 and Thompson, 1960) viz:

$$e_d = A + B \cdot t \qquad (6)$$

where

- e_d is the R.M.S. height error obtained from the contours;
- A is a constant which is usually slightly larger than the R.M.S. height error for individually measured points using the mapping instrument involved (Gustafson, 1977);
- B is a constant which reflects the horizontal shift in a contour; and
- t is the tangent of the angle of the terrain slope.

The errors were accordingly grouped into 10 slope classes. Nine classes from 0° to 14° and the tenth for slopes larger than 14°. This is because, in the two test areas, terrain with slope angle larger than 14° formed a small fraction of the whole area. The table on page 1 of Appendix A gives the slope classes, the corresponding slope angle, and its tangent.

The coefficients A and B of equation (6) were calculated using least squares adjustment. Appendix A gives for each participant the number of points tested in each slope class, the maximum and minimum errors and the R.M.S. errors for each algorithm. The table gives also the R.M.S. error for all of a participant map. The last line of each table gives the Koppe's formula for the result obtained from each of the two algorithms. Examining the result tables in Appendix A we may note the following:

(1) The R.M.S. errors evaluated by the Weighted Mean and the coefficients of Koppe's formula for this algorithm tend to be smaller than those evaluated using the Linear Interpolation algorithm. This may be explained by the fact that the height interpolated by the Weighted Mean (Equation (3)) is such that the effect of a point on the interpolated height changes quite rapidly as a function of the distance between the point and the position for which the interpolation is carried out. In this test, such position was on a standard contour and unless the error was quite large, tends to be closer to one of a participant's contours with same height. The interpolated height tends, therefore, to be biased in favour of that contour value and hence the error tends to be less.

(2) The distribution of the errors was found to be approximately normal. Accordingly, it is possible to evaluate whether the accuracy obtained for each participant satisfies the usually adopted Map Accuracy Standards which specify that 90% of the test points should be within one-half the contour interval. For contour interval of 1 m of the 1:6000 scale photography, and considering the R.M.S. error evaluated for all points tested, all participants satisfy such standard or barely do so. This is based on the assumption that the 1:3000 "standard" data are errorless.

It is possible that the errors in the 1:3000 photography have favourably biased the figures obtained in the test. If this is the case, the above mapping standard is not satisfactory for 1 m contour interval.

For the small scale test, and for 10 m contour interval, the above mapping standard is satisfied with a margin of 1.3 m for two of the participants. The other two have a margin less than one metre. The situation is, therefore, better than in the case of large scale photography in that at least two participants have margin for any biases in the results due to errors in the "standard" photography used.

(3) Comparing the A and B coefficients for the small scale test with those of the International Test Specifications of ISP for the 1:50 000 mapping given by Thompson (1960) as:

$$e_d = (1 + 7.5\ t) \text{ metres}$$

we find that B for all participants is well within that of ISP whilst A can be as large as twice that of ISP. The digital approach may explain the improvement in the B coefficient.

(4) The maximum error is about one contour interval (10 m) for the small scale test and can be about 1.5 times the contour interval for the large scale test.

ANALYSIS OF PLANIMETRIC RESULTS

The Area Method resulted in one value e_a which is an average deviation for the segment tested. The Generated Point Method resulted in one deviation value e_g for each point generated. The root mean square error for each feature was computed. To have another measure comparable with e_a, the mean of e_g for each feature was also computed. It was found, as we shall see below, that the Area Method tends to under-estimate the error while the Point Method tends to over-estimate it. It was, therefore, decided to compute the average of e_a and of the mean of e_g. This figure should be a good estimate of the average deviation of each feature. Appendix B gives the results of the two planimetric tests.

The over-estimation of the Point Method occurs usually when the generated points on a "standard" line do not correspond to points on the participant's segment. Such is the case when some generalization of the participant's data unavoidably occurs due to the reduction in the scale of the photography relative to the "standard" data. Figure 7 illustrates this position. The length of the "standard" segment tends to be larger than its corresponding one of a participant. The generated points on the two segments may not exactly correspond and hence the over-estimation of the method.

A case where the Area Method under-estimates the errors is when a lateral shift of part of a segment or the whole of it occurs. One segment of the large scale test was found to illustrate well the over-estimation and under-estimation problems. This is shown in Figure 8 and Figure 9. In Figure 8 it appears that points numbered 25 to 30 on the two segments do not correspond very well resulting in over-estimation of the Point Method in that part. In the part enlarged in Figure 9, the Point Method gives a better estimation of the error than the Area Method.

The above analysis can be seen from the results in Appendix B, where the figures in column (6) are always larger than/or equal to those in column (3) for each participant. It may also offer some explanation for the error of point features, such as buildings having a mean error in column (6) slightly larger than the average error of continuous features such as roads and railways in column (3) - a result which contradicts the expected higher accuracy of point features.

Further analysis of the results yields the following observations:

(1) Direct digitization from stereomodels can be more accurate than digitization from maps or orthophotos by a factor as high as 2.

(2) Considering all the results and the underestimation problem mentioned above, well-defined line features such as railways and roads can provide an accuracy comparable to point features. (This observation seems also to hold in the case of digitization from maps and orthophotos.

(3) As expected, for well-defined features the accuracy at photo-scale is independent of the scale of photography.

(4) The results of one participant (No. 12) tended to be consistently slightly better than those of other participants in both the small and large scale tests. (No editing was performed on his data.)

(5) The deviation e_g resulting from the Generated Points Methods lends itself better to statistical analysis than that from the Area Methods. The quantity represents a radial displacement which is always positive and, assuming no systematic deviations between the "standard" data and a participant's data, this deviation may have a normal bivariate distribution giving a "Mexican Hat" surface. Intuitively, the azimuth of the deviation vector takes any value from 0 to 2 π . If we assume that any horizontal cross-section of the surface is circular and that 50% of the deviations are contained within an angle π , then it is possible to attach a probability figure to the R.M.S. error of e_g in column 6. Accordingly, for some well defined features digitized from stereo-models, we expect that 90% of the points deviate by about 1 m or less in the case of the 1:6000 data and by 6 m or less in the case of 1:50 000 data from the "standard" (with scales 1:3000 and 1:15 000 respectively).

(6) An interesting treatment of the distribution of such radial displacements is given in White (1977). The treatment requires the computation of the standard deviation of e_g (column 7 in Appendix B). According to this treatment, we should expect 57.6% of the tested points to have deviations equal to or less than twice the figures of Column 7. Applying this approach to the results obtained in this test, 90% probability would include points with larger error than those reported under 5.

(7) There seems to be some consistency between the results obtained from the two methods used and between different participants for well defined features (first 4 lines of each table).

(8) Deducing the maximum possible enlargement for which the planimetric data is suitable and still meeting map accuracy standards may not prove possible because of errors in the "standard" data to be errorless. For both 1:50 000 and 1:6000, and using 1.64 time the figures in column (6), it can be seen that 5 times enlargement is only possible for some features and some participants.

TIME COMPARISON

In an attempt to compare the efficiency of different equipment and methods used for the acquisition of digital topographic data, participants were asked to keep a careful record of the time spent for each phase of the work. They were also asked to provide a description of the technical qualifications and experience of the personnel employed at each production phase as well as to indicate a relative wage for each employee based on the lowest wage level. Detailed instructions to prepare the "Cost Perspective" were given to the participants (see Appendix C). Their replies can be found in Appendices D and E.

A meaningful comparison and analysis of these answers proved to be difficult for a number of reasons:

1. In general, too many factors influenced the times reported and many of them were unrelated to our study. For instance, most participants used spindle driven instruments, but two digitized the data with hand driven plotters giving them a significant advantage. The impact of the operator's efficiency on the time reported is impossible to estimate, but based on the authors' experience it cannot be negligeable. Operator's training in the use of the digitizing and editing equipment is another factor which is likely to bias the results.

2. Many participants did not carry out the test in full. Some digitized and partly processed only 1 or 2 stereo-models, others digitized only planimetric detail while a third group digitized only height data. It is obviously impossible to use the results of these participants in a meaningful way.

3. One participant digitized a plot and an orthophoto but unfortunately did not report his time.

4. A few participants digitized more detail than required thus increasing the time for data acquisition.

5. Finally, an attempt to combine the time reported with the unit wage cost yielded meaningless results. We therefore decided to consider only the time reported for data acquisition and editing.

Despite these difficulties, a few tentative conclusions emerge from a careful analysis of the results:

1. Clean, accurate data for large scale mapping can be acquired efficiently without the use of an interactive graphic system on-line with the stereoplotter. This conclusion is supported by comparing times reported by participants No. 1, 8, 14 with those of participants No. 3 and 6.

2. Clean, accurate data for small scale mapping can also be acquired without an interactive graphic system on-line with the stereoplotter. However, and this conclusion is based on three participants only (No. 6, 8 and 14), there appears to be a time penalty for not having the flexibility afforded by interactive graphic capability at the photogrammetric station.

3. As can be expected, users of outdated equipment (see participant No. 13) registering data in point mode, pay a heavy time penalty both at the data acquisition phase and at the editing phase.

There is little doubt in the mind of the authors that these results should be used with caution as they are based on a very small sample of participants performing a test limited in scope. The reader should also consider that participants were given specific instructions on the detail to digitize. These instructions took the form of a plot showing exactly which features - houses, railway, fences, etc., - had to be digitized. The work, therefore, did not require any judgment on the part of the operator, decisions were kept to a minimum and, consequently, few errors were made that needed corrections. Without doubt real-life situations would require a fair amount of interpretation and judgment on the part of the operator- especially in the case of small scale maps - which would increase the time required to perform a similar task to the ISP test and might give some advantage to fully interactive graphic systems.

CONCLUSION

Although interesting deductions can be made from the results of this international test, the limited scope of the two tests (4 stereo-models), the necessary restrictions imposed on the participants to ensure comparability, and the small number of useful results must be considered when drawing conclusions.

At the outset it was intended to find out or confirm that some methods of digital mapping yielded more or less accurate results than others or were more or less efficient than others. Not unexpectedly, it is clear that digitizing topographic detail on photogrammetric instruments allows one to conserve the inherent accuracy of the photogrammetric process. By contrast, plotting the detail first on a manuscript that is to be digitized later results in a significant loss in accuracy even with a manuscript twice the scale of the photographs. This accuracy deteriorates even further when digitizing an orthophotomap.

However there seems to be little evidence to conclude that interactive digitizing or editing does anything to improve the accuracy of the final product. The usefulness of an interactive graphic systems in mapping must be found elsewhere such as in cleaning up the data or, possibly in some improvement in the efficiency. Comparison of the accuracy of point features versus linear features showed some interesting and somewhat surprising results since the latter seems to be consistently more accurate than the former.

Several other deductions concerning accuracy (in particular the possibility of enlarging digitized topographic data 4 or 5 times) are given in the paper and will not be repeated here.

As for the time comparison, it is clear that users of outdated digitizing equipment pay a heavy time penalty. Although no attempt could be made in the context of this test to work out the overall cost-benefit of a modern digitizing system compared to an older one, it seems likely that, unless little digitizing has to be done, outdated equipment is inefficient. However one needs not, at least for large scale mapping, invest in a powerful and expensive digitizing system. The results of participant No. 14 show that good quality data can be obtained efficiently with a simple, unsophisticated system.

This conclusion does not seem to be true for small scale mapping although the nature and scope of the test, and the small number of participants make this conclusion difficult to confirm.

Recommendations for Future Tests

In retrospect, we believe that the four factors tested - large and small scale accuracy on the one hand, and large and small scale efficiency on the other - should be the object of four distinct experiments. If at all possible, future tests should be conducted in such way that extraneous factors such as operator efficiency and type of photogrammetric instruments, should be eliminated or carefully controlled to limit their influence on the results.

The accuracy of the "standard" data should have been better guaranteed. To this effect the "standard" data should be collected on an analytical plotter where corrections can be applied to errors such as film distortion which, in another investigation by one of the authors, has been found to be larger than expected. The "standard" data should also have been checked with ground measurements. This would have helped to provide more reliable conclusions regarding the maximum acceptable enlargements.

Finally some assumptions had to be made when estimating the errors of line features since no point to point correspondence can be established between two lines. Further work is necessary to determine the effect of over-estimation and under-estimation discussed previously. We recommend that the ISP, after due consideration of the various methods available to determine the accuracy of linear features, select and approve one algorithm which can then be used in future tests.

REFERENCES AND BIBLIOGRAPHY

1. Blachut, T.J. and M.C. van Wijk; 1976, "Results of the International Orthophoto Experiment 1972-1976", Photogrammetric Engineering and Remote Sensing, vol. 42, no. 2, 1433-1498.

2. Blakney, W.G.G.; 1968, "Accuracy Standards for Topographic Mapping", Photogrammetric Engineering, vol. 34, no. 10, 1040-1042.

3. Finsterwalder, R.; 1974, "Zur Beurteilung der Geländedarstellung in topographischen Karten", Société Française de Photogrammétrie, Bulletin #57, Commission IV Symposium, Paris, 9-16.

4. Gustafson, G.C.; 1977, "Koppe Errors in Automatic Contouring", Proceedings of the American Congress on SUrveying and Mapping, 37th Annual Meeting, Washington, D.C., 305-317.

5. Kraus, K.; 1970, "Interpolation nach kleinsten Quadraten in der Photogrammetrie", Zeitschrift für Vermessungswesen, Nr 9, 387-390.

6. Lindig, Gerhard; 1956, "Neue Methoden der Schichtlinienprufung", Zeitschrift für Vermessungswesen, Nr 7/8, 244-296.

7. Moritz, H.; 1964, "Zur Genauigkeit der Höhenschichtlinien", Zeitschrift für Vermessungswesen, Nr 12, 453-456.

8. Morrison, J.L.; 1974, "Observed Statistical Trends in Various Interpolation Algorithms Useful for First Stage Interpolation", Canadian Cartographer, vol. 11, 142-159.

9. Shewell, H.A.L.; 1951, "Accuracy of Contours", Journal of the Royal Institute of Chartered Surveyors, vol. 31, no. 4, 195-215.

10. Standardization Agreement; 1970, Military Agency for Standardization, NATO, STANAG No. 2215, Edition No. 3.

11. Thompson, M.M. and H.D. Charles; 1963, "Vertical Accuracy of Topographic Maps", Surveying and Mapping, vol. 13, no. 1, 40-48.

12. Thompson, M.M.; 1956, "How Accurate is that Map", Surveying and Mapping, vol. 16, no. 2, 164-173.

13. Thompson, M.M.; 1960, "A Current View of the National Map Accuracy Standards", Surveying and Mapping, vol. 20, no. 4, 449-457.

14. White, L.A.; 1977, "Distribution of Contouring", The Australian Surveyor, vol. 28, no. 8.

ACKNOWLEDGEMENTS

Once more, thanks are due to the participants in the test. The authors wish to also acknowledge the help and cooperation of G. Gibbons, H. Rice and E.W. Kerr of Topographical Survey, Surveys and Mapping Branch, Ottawa, and N. Lee, V. Oliver and B. Mersereau of the Univeristy of New Brunswick. Thanks are also due to Wild of Canada for providing the AMH instrument used in the collection of "standard" data. Mrs. M. Padin's excellent typing of the manuscript is much appreciated.

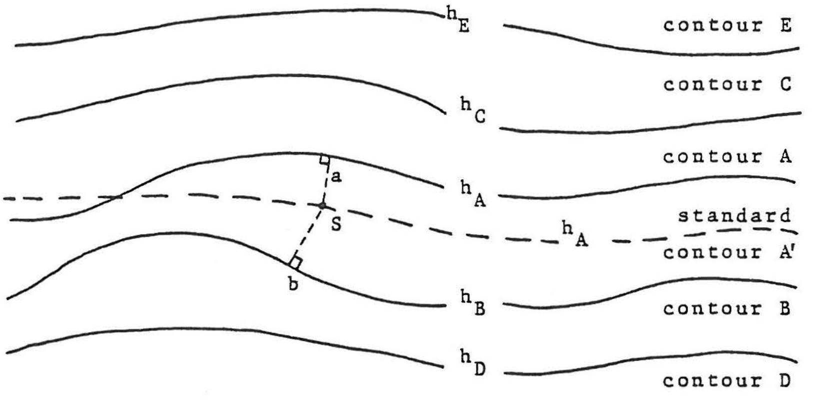

Fig. 1: Point S is a point of the standard contour A' at which the height is interpreted from the participant's data.

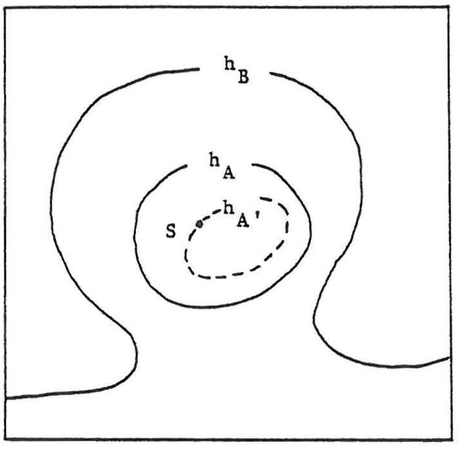

Fig. 3: Contour $h_{A'}$ will be eliminated from the test. The entire $h_{A'}$ is enclosed by a participant's contour and therefore its height can only be extrapolated.

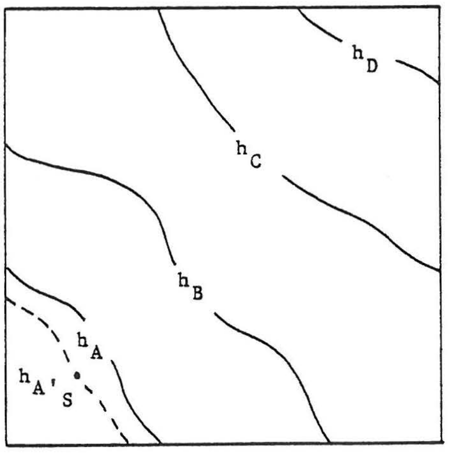

Fig. 2: Contour $h_{A'}$ will be eliminated from the test. The entire $h_{A'}$ is outside range of participant's contours and therefore its height can only be extrapolated.

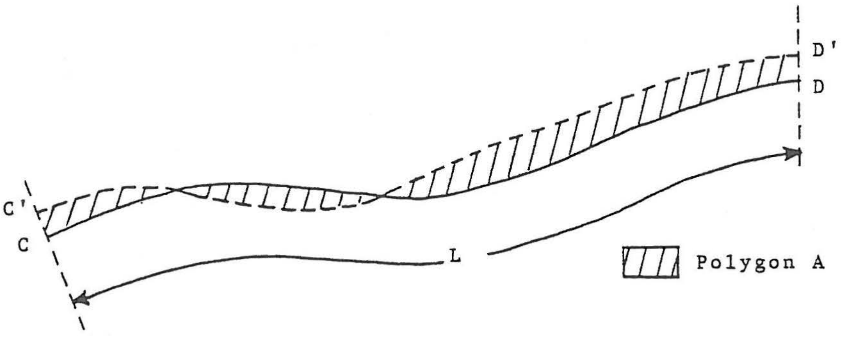

Fig. 4: The area method to evaluate the planimetric accuracy.

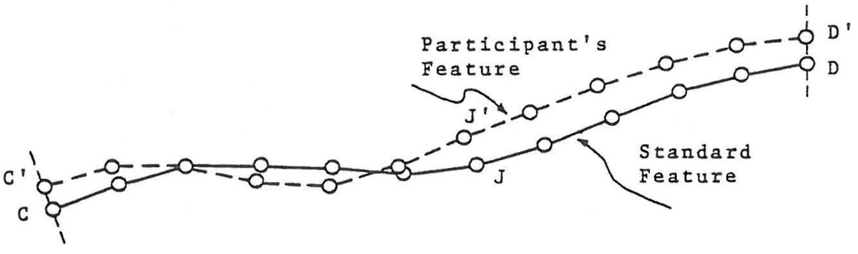

Fig. 5: The Generated Point Method to evaluate the planimetric accuracy.

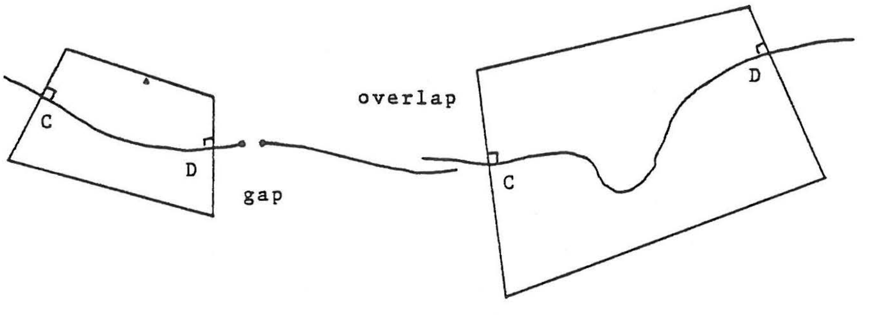

Fig. 6: Standard segments are selected using a window with two sides approximately perpendicular to the feature at the end points C and D. Visible gaps and overlaps were excluded.

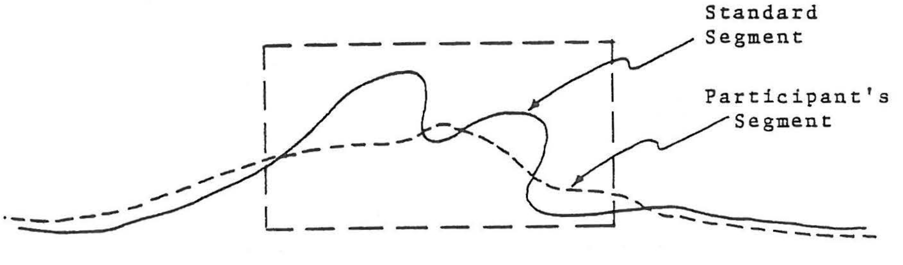

Fig. 7: Generalization of a participant's data due to the relatively smaller scale used causes the Point Method to overestimate the errors calculated. The generalization is illustrated in the dashed rectangle.

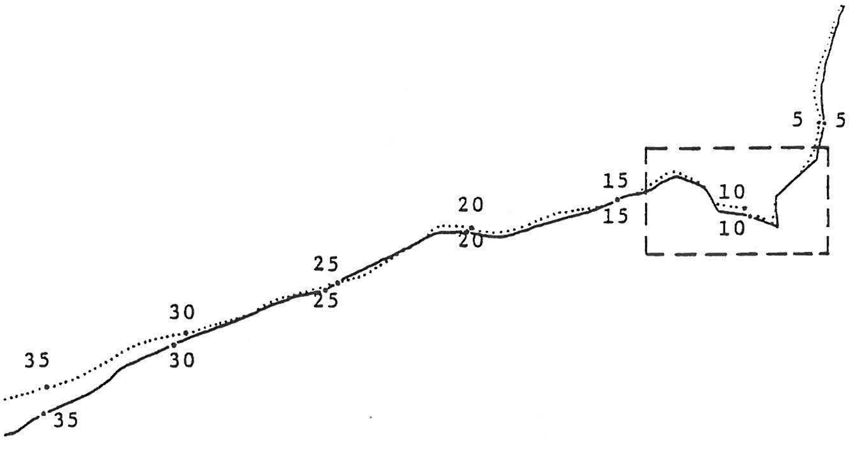

Fig. 8: A standard segment of the large scale test (solid line) and the corresponding segment from a participant's data (dotted). Parts of the segments inside rectangle is enlarged in Figure 9.

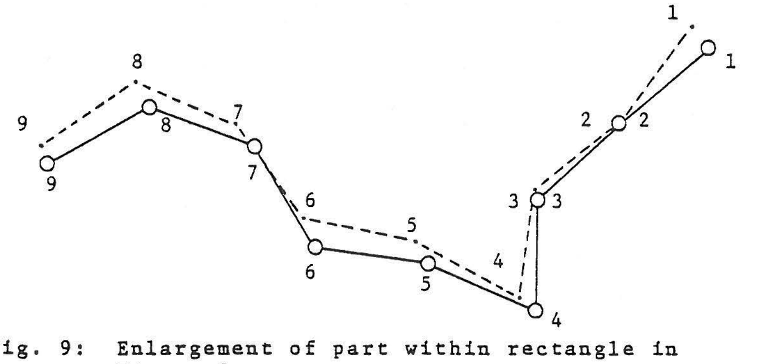

Fig. 9: Enlargement of part within rectangle in Figure 8.

APPENDIX A

RESULTS OF HEIGHT TESTS

This appendix gives the results of the large scale test followed by the small scale. The points were grouped in 10 slope classes as follows:

Slope Class	Degree of Slope θ	Tangent of SLope $\tan\theta$
1	0.0 - 0.6	0.000 - 0.010
2	0.6^{+} - 0.8	0.010^{+} - 0.015
3	0.8^{+} - 1.4	0.015^{+} - 0.025
4	1.4^{+} - 2.9	0.025^{+} - 0.050
5	2.9^{+} - 4.3	0.050^{+} - 0.075
6	4.3^{+} - 5.7	0.075^{+} - 0.100
7	5.7^{+} - 8.5	0.100^{+} - 0.150
8	8.5^{+} - 11.3	0.150^{+} - 0.200
9	11.3^{+} - 14.0	0.200^{+} - 0.250
10	14.0^{+}	0.250^{+}

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 6

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	26	0.48	0	0.22	0.49	0.01	0.29
2	106	0.97	0	0.22	0.78	0.0	0.22
3	281	1.18	0	0.20	0.77	0.0	0.20
4	708	1.28	0	0.21	0.85	0.0	0.22
5	435	1.20	0	0.20	1.39	0.01	0.25
6	263	0.97	0	0.15	0.87	0.01	0.21
7	237	1.26	0	0.26	1.06	0.02	0.30
8	94	1.06	0	0.38	1.22	0.02	0.39
9	43	1.21	0	0.42	0.86	0.03	0.40
10	102	1.56	0	0.51	1.57	0.03	0.50
Map	2295	1.56	0	0.24	1.57	0	0.26
Koppe Formula		$0.18 + 0.87 \tan\theta$			$0.21 + 0.76 \tan\theta$		

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 8

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	16	0.57	0	0.15	0.12	0.0	0.17
2	98	0.74	0	0.30	1.35	0.01	0.33
3	254	1.17	0	0.29	1.12	0.01	0.29
4	654	1.31	0	0.22	1.54	0.01	0.26
5	465	1.48	0	0.23	1.56	0.01	0.27
6	236	1.0	0	0.26	0.96	0.0	0.28
7	181	1.01	0	0.34	1.19	0.02	0.35
8	77	1.01	0	0.41	0.85	0.03	0.39
9	44	1.06	0	0.50	1.26	0.04	0.49
10	70	1.12	0.01	0.61	1.51	0.08	0.59
Map	2095	1.48	0	0.29	1.56	0	0.31
Koppe Formula		$0.21 + 1.0 \tan\theta$			$0.24 + 0.93 \tan\theta$		

PARTICIPANT No. 12

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	28	0.30	0	0.15	0.41	0.0	0.21
2	106	0.62	0	0.15	0.73	0.0	0.21
3	328	0.99	0	0.19	0.80	0.0	0.23
4	768	0.99	0	0.25	0.99	0.0	0.18
5	448	1.05	0	0.25	1.22	0.0	0.29
6	248	0.96	0	0.24	0.95	0.01	0.29
7	167	0.99	0	0.26	0.75	0.03	0.29
8	83	1.01	0.01	0.38	0.79	0.07	0.39
9	49	0.86	0	0.37	0.72	0.08	0.42
10	64	0.95	0	0.40	0.83	0.02	0.42
Map	2289	1.05	0	0.25	1.22	0	0.28
Koppe Formula		$0.19 + 0.66 \tan\theta$			$0.23 + 0.59 \tan\theta$		

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 6

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	566	5.4	0	1.6	3.2	0	1.2
2	754	11.4	0	1.4	8.4	0	1.7
3	965	12.5	0	2.8	9.6	0	2.8
4	863	11.4	0	2.1	9.3	0	2.3
5	243	8.5	0	1.7	7.1	0	2.3
6	169	4.1	0	0.9	5.6	0.1	1.7
7	165	5.7	0	1.4	5.4	0.2	2.0
8	79	3.5	0	0.9	4.2	0.3	1.8
9	34	2.8	0	0.7	3.8	0.4	1.9
10	57	9.8	0	3.1	9.2	0.2	3.6
Map	3895	12.5	0	2.0	9.6	0	2.2
Koppe Formula		$1.5 + 1.3 \tan \theta$			$1.7 + 3.3 \tan \theta$		

PARTICIPANT No. 8

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	571	6.3	0	1.3	3.0	0	1.1
2	587	5.1	0	1.0	4.9	0	1.4
3	1021	9.6	0	3.0	8.5	0	3.0
4	794	8.8	0	1.9	7.0	0	2.2
5	256	1.0	0	2.0	9.1	0.1	2.4
6	170	9.9	0	1.9	9.0	0.1	2.5
7	174	5.0	0	1.2	5.2	0.1	2.1
8	66	6.6	0	1.8	5.9	0.4	2.6
9	28	6.7	0	2.4	7.1	0.6	3.0
10	49	9.1	0	4.1	7.7	0.3	4.1
Map	3716	9.9	0	2.1	9.1	0	2.3
Koppe Formula		$1.5 + 5.2 \tan \theta$			$1.8 + 5.6 \tan \theta$		

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 12

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	647	3.4	0	0.6	3.8	0	1.3
2	579	9.3	0	1.6	9.8	0	2.2
3	1080	10.2	0	3.2	10.0	0	3.4
4	903	10.1	0	3.3	9.9	0	3.6
5	272	10.0	0	3.1	9.7	0.1	3.6
6	143	9.9	0	2.4	9.3	0	2.8
7	89	7.0	0	2.1	6.8	0.2	2.9
8	56	8.0	0	2.5	7.4	0.3	3.3
9	20	5.6	0	2.1	5.3	0.6	3.2
10	24	9.5	0	3.1	8.6	0.4	3.7
Map	3813	10.2	0	2.7	10.0	0	3.0
Koppe Formula		$2.2 + 2.0 \tan\theta$			$2.7 + 2.9 \tan\theta$		

PARTICIPANT No. 14

		WEIGHTED MEAN			LINEAR INTERPOLATION		
SLOPE CLASS	NO. OF POINTS	MAX (m)	MIN (m)	RMS (m)	MAX (m)	MIN (m)	RMS (m)
1	559	8.3	0	2.0	10.1	0	3.7
2	572	11.1		1.3	7.7	0	1.6
3	1059	13.0	0	2.7	9.9	0	2.6
4	853	10.0	0	2.1	9.5	0	2.5
5	319	9.2	0	1.7	7.7	0.1	2.3
6	182	9.9	0	1.8	9.3	0.2	2.3
7	149	5.7	0	1.6	5.4	0.3	2.5
8	56	7.4	0	2.0	6.2	0.6	2.8
9	22	5.6	0.1	2.8	6.2	0.1	3.6
10	27	9.4	0	3.4	8.5	0.3	4.1
Map	3789	13.0	0	2.1	10.1	0	2.6
Koppe Formula		$1.7 + 3.5 \tan\theta$			$2.3 + 4.0 \tan\theta$		

APPENDIX B

RESULTS OF PLANIMETRIC TESTS

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 6

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AREA METHOD AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	POINT METHOD MEAN (m) (5)	POINT METHOD RMS (m) (6)	POINT METHOD SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	656	2.9	4.5	3.5	2.9
Power Line, Tower	-	-	25	2.4	2.6	1.1	2.4
Road	101	1.9	5345	2.3	2.9	1.8	2.1
Railway	3	2.0	537	2.7	3.1	1.5	2.4
Single Line Stream	21	2.6	710	6.6	8.6	5.5	4.6
Double Line Stream or Lake	8	3.1	639	5.7	7.0	4.1	4.4
Ditch	3	3.7	110	3.9	4.2	1.7	3.8

REMARKS: Wild AMH Interactive Stereo Digitizing

PARTICIPANT No. 8

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AREA METHOD AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	POINT METHOD MEAN (m) (5)	POINT METHOD RMS (m) (6)	POINT METHOD SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	600	2.9	4.6	3.5	2.9
Power Line, Tower	-	-	24	2.9	3.3	1.6	2.9
Road	40	2.6	1972	3.1	4.3	3.0	2.9
Railway	-	-	-	-	-	-	-
Single Line Stream	21	2.9	1451	11.0	14.2	8.8	7.0
Double Line Stream or Lake	8	6.9	639	14.2	18.7	12.1	10.6
Ditch	3	1.9	110	3.2	3.7	1.8	2.6

REMARKS: Kern PG-2 Blind Stereo Digitizing

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 9

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AREA METHOD AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	POINT METHOD MEAN (m) (5)	POINT METHOD RMS (m) (6)	POINT METHOD SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	615	5.4	6.4	3.3	5.4
Power Line, Tower	-	-	4	3.7	3.8	1.0	3.7
Road	75	5.4	3639	5.9	7.0	3.8	5.7
Railway	3	3.9	537	4.2	4.8	2.3	4.1
Single Line Stream	19	7.0	764	27.8	57.8	50.7	17.4
Double Line Stream or Lake	7	4.5	475	9.6	11.5	6.3	7.1
Ditch	3	5.4	110	5.7	6.7	3.5	5.6

REMARKS: Digitized from 1:20 000 plan plotted by WILD A-10

PARTICIPANT No. 9

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AREA METHOD AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	POINT METHOD MEAN (m) (5)	POINT METHOD RMS (m) (6)	POINT METHOD SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	131	8.1	12.7	9.9	8.1
Power Line, Tower	-	-	-	-	-	-	-
Road	64	4.0	3385	4.6	5.7	3.3	4.3
Railway	2	4.9	362	5.3	6.2	3.3	5.1
Single Line Stream	19	5.3	789	10.4	13.6	8.8	7.9
Double Line Stream or Lake	6	6.5	523	12.1	15.5	9.6	9.3
Ditch	3	4.8	110	5.0	5.9	3.2	4.9

REMARKS: Digitized from 1:20 000 orthophotos

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 12

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	654	2.8	4.1	3.0	2.8
Power Line, Tower	-	-	25	2.7	3.2	1.8	2.7
Road	77	1.7	4255	1.9	2.3	1.3	1.8
Railway	1	1.1	143	1.6	1.8	0.9	1.4
Single Line Stream	15	2.6	1150	11.8	15.4	9.9	7.2
Double Line Stream or Lake	4	1.9	217	4.0	4.9	2.9	3.0
Ditch	2	1.8	83	1.8	2.1	1.0	1.8

REMARKS: Wild A-8, Blind Stereodigitizing
Standard error when instrument was last calibrated:
$Sx = \pm 8\ \mu m$, $Sy = \pm 14\ \mu m$, $Sz = \pm 6\ \mu m$

PARTICIPANT No. 14

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	652	3.3	4.4	2.9	3.3
Power Line, Tower	-	-	25	3.1	3.9	2.4	3.1
Road	98	2.2	5395	2.6	3.3	2.0	2.4
Railway	3	1.4	537	1.7	2.0	1.1	1.6
Single Line Stream	17	3.0	1052	11.0	13.9	8.5	7.0
Double Line Stream or Lake	8	4.0	433	7.5	9.0	5.0	5.8
Ditch	3	2.5	110	2.6	2.8	1.1	2.6

REMARKS: Wild A-8 Blind Stereo Digitizing

SMALL SCALE TEST-WEST BLOCK

PARTICIPANT No. 16

	AREA METHOD		POINT METHOD				MEAN OF
FEATURE	No. OF SEGMENTS	AVERAGE ERROR	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	192	3.9	4.7	2.7	3.9
Power line, Tower	-	-	8	5.1	5.3	1.7	5.1
Road	46	2.5	2477	3.0	3.6	2.1	2.8
Railway	2	2.8	318	3.3	3.5	1.3	3.1
Single Line Stream	10	3.0	680	17.5	28.8	22.9	10.3
Double Line Stream or Lake	3	1.8	162	4.6	5.3	2.6	3.2
Ditch	1	2.5	27	2.7	2.9	1.2	2.6

REMARKS: WILD A-7 Blind Stero Digitizing,
2 models only,
Standard error when instrument was last calibrated:
$Sx = \pm 6.57\ \mu m$, $Sy = \pm 6.57 \mu m$
$Sz = \pm 3.95\ \mu m$

RESULTS OF PLANIMETRIC TESTS

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 6

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	456	0.38	0.48	0.29	0.38
Fence	6	0.22	407	0.23	0.30	0.19	0.23
Power line, Tower	-	-	300	0.45	0.63	0.44	0.45
Road	22	0.32	2049	0.37	0.63	0.52	0.35
Railway	9	0.18	1185	0.19	0.23	0.13	0.19
Single Line Stream	5	0.78	300	1.48	2.02	1.37	1.13
Double Line Stream or Lake	20	0.83	2966	2.23	3.10	2.16	1.53
Ditch	11	0.33	1367	0.45	0.56	0.34	0.39

REMARKS: Wild AMH Interactive stereo Digitizing

PARTICIPANT No. 8

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	428	0.45	0.69	0.52	0.45
Power line, Tower	-	-	284	0.49	0.60	0.35	0.49
Road	18	0.43	1735	0.49	0.75	0.57	0.46
Railway	8	0.25	1093	0.26	0.32	0.20	0.26
Single Line Stream	4	1.06	261	1.64	2.16	1.40	1.35
Double Line Stream or Lake	19	1.18	2841	2.72	3.69	2.49	1.95
Ditch	11	0.55	1367	0.68	0.91	0.60	0.62

REMARKS: Kern PG-2 Blind Stereo Digitizing

LARGE SCALE TEST- EAST BLOCK

PARTICIPANT No. 9

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	MEAN (m) (5)	RMS (m) (6)	SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	442	1.31	1.60	0.91	1.31
Fence	3	1.11	201	1.27	1.94	1.47	1.19
Power Line, Tower	-	-	164	1.07	1.28	0.69	1.07
Road	16	0.96	1368	1.03	1.24	0.68	1.00
Railway	3	0.59	462	0.59	0.69	0.36	0.59
Single Line Stream	4	2.27	211	3.94	5.35	3.62	3.11
Double Line Stream or Lake	13	2.90	1684	3.37	4.67	3.23	3.14
Ditch	6	0.70	836	0.81	0.98	0.56	0.76

REMARKS: Digitized from 1:2000 Orthophotos

PARTICIPANT No. 9

FEATURE (1)	AREA METHOD No. OF SEGMENTS (2)	AVERAGE ERROR (m) (3)	POINT METHOD No. OF POINTS (4)	MEAN (m) (5)	RMS (m) (6)	SD (m) (7)	MEAN OF COLUMNS 3 & 5 (m)
Building	-	-	445	0.86	0.97	0.44	0.86
Fence	5	0.79	352	0.82	0.90	0.38	0.81
Power Line, Tower	-	-	297	0.83	0.92	0.38	0.83
Road	14	0.74	1267	0.78	1.03	0.67	0.76
Railway	2	0.35	203	0.36	0.46	0.29	0.36
Single Line Stream	5	1.71	300	2.53	3.28	2.09	2.12
Double Line Stream or Lake	15	0.98	1906	2.01	2.83	2.00	1.50
Ditch	3	0.62	231	0.83	0.97	0.51	0.73

REMARKS : Digitized from 1:2000 plan plotted on WILD A-10

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 11

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	454	0.29	0.42	0.30	0.29
Power Line, Tower	-	-	284	0.38	0.66	0.54	0.38
Road	21	0.36	1997	0.40	0.60	0.72	0.38
Railway	9	0.10	1185	0.11	0.13	0.07	0.11
Single Line Stream	4	1.98	261	2.60	3.77	2.73	2.29
Double Line Stream or Lake	11	0.81	1968	3.10	4.42	3.15	1.96
Ditch	12	0.38	1454	0.48	0.58	0.34	0.43

REMARKS: Wild A-10 Blind Stereo Digitizing
Standard error when instrument was last calibrated:
$Sx = \pm 3$ μm , $Sy = \pm 7$μm , $Sz = \pm 9$ μm

PARTICIPANT No. 12

	AREA METHOD		POINT METHOD				MEAN
FEATURE	No. OF SEGMENTS	AVERAGE ERROR (m)	No. OF POINTS	MEAN (m)	RMS (m)	SD (m)	OF COLUMNS 3 & 5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Building	-	-	452	0.27	0.38	0.27	0.27
Power Line, Tower	-	-	275	0.27	0.36	0.24	0.27
Road	18	0.28	1663	0.31	0.57	0.48	0.30
Railway	6	0.12	866	0.13	0.17	0.10	0.13
Single Line Stream	5	0.68	300	1.06	1.37	0.86	0.87
Double Line Stream or Lake	15	0.88	2497	2.22	3.21	2.32	1.55
Ditch	12	0.36	1454	0.52	0.66	0.40	0.44

REMARKS: Wild A-8 Blind Stereo Digitizing
Standard error when instrument was last calibrated:
$Sx = \pm 8$ μm , $Sy = \pm 14$μm , $Sz = \pm 6$ μm

APPENDIX C

INSTRUCTIONS TO PARTICIPANTS FOR PREPARING THE COST PERSPECTIVE

1. While it is considered necessary to provide some information regarding the costs of digital data acquisition, it is recognized that the various aspects of capital amortization; salaries; national policies such as import duties and tariffs; international exchange rates, make any rigorous analysis of costs impractical.

2. In lieu of the more usual numerical cost related data it has therefore been decided to request that each participant provide sufficient descriptive information to enable a relative "cost perspective" to be deduced. This information required is best illustrated by the attached examples and include the five mandatory columns for:

   (a) Equipment resources description outlining the types and quantities of equipment utilized.

   (b) Manpower resources description outlining the type and technical qualification of the personnel employed at each stage of production.

   (c) Progress description outlining the various phases or stages of production.

   (d) Time expenditure. The man-hours expended at each phase of the production/test process.

3. Unit wage cost. A quantity which describes the relative wage costs for the different manpower resources applied. The quantity is derived by assigning unity (1.0) as representing the lowest wage level and all other wage levels are shown in proportion.

APPENDIX D

TIME COMPARISON

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT	DATA ACQUI- SITION (hours)	EDITING (hours)	REMARKS	COMMENTS
8	21	32	Blind stereodigitizing with hand driven intrument (PG-2). Editing with an interactive graphic system.	Complete data. Minor gaps and overlaps, but data essentially clean.
6	35.5	12.5	Interactive stereodigitizing with spindle driven instrument (AMH). Editing with an interactive graphic system.	Complete data. Minor overlaps, but data essentially clean.
3	48	23	Interactive stereodigitizing with hand driven instrument (B-8S) Editing with an interactive graphic system.	Data could not be processed. Lack of training may explain amount of time spent.
14	44	10.5	Blind stereodigitizing with spindle driven instrument (A-8). Editing using check plot and table digitizer.	Complete data. Minor gaps, but data essentially clean.
12	50	none	Blind stereodigitizing with spindle driven instrument (A-8), EK-8 and fast paper tape punch. - no editing.	Many mistakes in otherwise complete data (feature code missing, some overlaps, etc).
11	37	2.5	Blind stereodigitizing with hand driven instrument (A-10) and EK-8. Interactive editing.	Planimetry only. Some errors in data (e.g. missing house corners). No major problems. Lines not very smooth.
1	34.5	6.5	Blind stereodigitizing with spindle driven instrument (Planimat) and Gradicon digitizer - Editing using check plot and table digitizer	Complete data. Essentially clean data.
5	47	1.5	Blind stereodigitizing with spindle driven instrument (Planimat) on-line with PDP-11/45-Interactive editing.	Complete planimetry. Some contours missing, replaced spot heights.

LARGE SCALE TEST - EAST BLOCK (Con't)

PARTICIPANT	DATA ACQUI-SITION (Hours)	EDITING (Hours)	REMARKS	COMMENTS
13	90	40	Blind stereodigitizing with spindle driven instrument (A-7) and EK-5. Point recording mode only. Interactive editing.	Planimetry and DTM for the whole area. Overlap between segments, some missing detail (e.g. house corners).
18	21	5	Interactive stereodigitizing with spindle driven instrument (Planicomp). Editing with an interactive graphic system.	2 models only
4	42	-	Blind stereodigitizing with spindle driven instrument (A-7).	2 models only. Minor gaps and overlaps in data. Widely spaced points. - no time reported for editing.
2	16.5	3	Blind stereodigitizing with spindle driven instrument (A-7) and EK-10.	2 models only. Minor gaps and overlaps in data. Widely spaced points.
7	15		Blind stereodigitizing with spindle driven instrument (A-7) and EK-5.	Planimetry and DTM. No contours. Very little planimetric detail. Spurious lines. 1 model only. - no editing reported.
10	3		Blind stereodigitizing with spindle driven instrument (A-7) and EK-8.	1 model only. Planimetry, DTM and contours. Essentially clean data.

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 1

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Planimat Stereoplotter Instronics Gradicon Digitizer Cabinet	Stereoplotting "Blind Digitizing"	34.5	1.3	Photogrammetrist Technologist level
PDP-11/45 CPU-44K memory Two RK05 Discs Two magnetic tape units	Production of Proof Plot Tape	3.5	1.0	Program initiated by Computer Operator
Kongsberg DM 1200 Draughting Machine Kongsberg 402 S Controller	Draughting of Proof Plots	0.9	1.1	Draughting initiated by Operator
Instronics Gradicon Cartographic Digitizer	Off-line Editing	3.5	1.3	Cartographer Technologist level
PDP-11/45-see above	Edit Processing	3.0	1.0	Program initiated by Computer Operator

PARTICIPANT No. 2 (2 models only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Autograph A7 (Wild) EK-70 Digitizer	Stereoplotting and Digitizing	16.5	1.2	Photogrammetrist Technologist level attained by 5 years on-job training.
FACOM 230-45S CPU-256KB Memory 9 Track 1600 Bpi Magnetic Tape Unit	Editing	3.0	1.2	Operator Technologist level attained by 6 years on-job training.
NUMERICON R-30125V	Proof Plot Off-line	0.5	1.0	Operator Employment level. attained by 6 months formal training.

PARTICIPANT No. 3

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Manual		23.00	1.0	Photogrammetric Operator/ Cartographic Draftsman
Wild B-8S stereoplotter M&S system consisting of PDP 11/34, 256 K bytes memory, 1 80 mb disc. 1 tape drive. Kongsberg flatbed plotter.	Interactive Digiti-zing	48.05	1.0	same
M&S System	Editing	23.30	1.0	same

PARTICIPANT No. 4 (2 models only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Wild A-7 Autograph EK-8 Digitizer Facit 4070 Paper Tape Puncher	Stereoplotting "Digitizing Plani-metric Details and Contours"	42.0	1.3	Photogrammetrist Technologist level attained by 5 years on-job training.
Burroughs B-4700 150 Byte Memory Fixed D26K 9 Track 800 bpi Magnetic Tape	Converting to magnetic tape from paper tape and editing CPU Time	9.0 0.1	1.2	Operator Technologist level attained by 2 years on-job training.
Numericon (Mutoh Industry, Ltd.)	Proof Plot "Programming" "Plotting"	38.0 0.7	1.2	Operator Technologist level attained by 3 years on-job training.

LARGE SCALE TEST - EAST BLOCK

PARTICIPANT No. 5

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Planimat P2 Stereoplotter with x,y,z shaft encoders attached. PDP 11/45 CPU 128 K Memory. 80 Megabyte disk storage. 7 track mag tape.	Stereoplotting on-line data acquisition & for file processing.	47.0	1.0	Senior Drafting Officer Cartography certificate Institute of Technology 10 years experience
Xynetics Flatbed Plotter 57" x 42". 40"/sec speed acceleration 1G. Driven off-line by HP 2100 8K memory.	Edit plots and final plot	5.0	1.0	Senior drafting Officer Cartography Certificate Institute of Technology 10 years experience
GT42 refresh graphics screen. Track table digitizer. (both on-line to PDP11/45)	Interactive and Manuscript Editing	1.5	1.0	Senior Drafting Officer Cartography Certificate Institute of Technology 10 years experience

PARTICIPANT No. 6

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Manual	Set up models & determine model-ground coordinate reference.	6.0	1.0	Photogrammetrist technologist level obtained by 6 years on-job training (DD5).
Wild AMH Stereoplotter with Cybernex D1600 Digitizer/ Terminal hardwired to M&S interactive graphic system consisting of PDP 11/45	Interactive digitizing	34.5	1.0	"
with 128 K memory, 2 RP04 38 mB discs, Tektronix 4014/613 dual screen graphic station, TU 10/TM 11 tape drive. On-line Calcomp 960 drum plotter.	Interactive editing	12.5	1.0	"
Editing station on-line with above M&S system	Proof plots	1.0	1.0	"
	Processing data (format conversion from internal format to ISP tape format)	1.5	1.0	"

REMARKS: Of the total digitizing time the portion required by each specific feature type is shown below:

Roads	25%
Hydrography	15%
Buildings	30%
Contours	30%

PARTICIPANT No. 7 (1 model only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Autograph A7 (Wild) EK-5 Digitizer	Stereoplotting Mesh & Linear Digitizing	15.0	2.0	Photogrammetrist Technologist level attained by 10 years on-job training.
MELCOM 9100 30F	Data Processing	2.0	1.42	Operator Employment level attained by 3 years formal training.

REMARKS: Grid interval of DTM is 30 m.

PARTICIPANT No. 8

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Kern PG-2 Stereoplotter Altek AC189 Digitizer	Stereoplotting "Parallel Digitizing"	21.2	1.35	Photogrammetric Technician with more than ten years of experience.
M&S Computing, Inc., System PDP-11/70 CPU-128K Memory Two 80 Megabyte Drives Three 800/1600 bpi Magnetic tape units	Editing Interactive Editing	32.0	1.0	Cartographer/Photogrammetrist with more than four years of experience.
Offline Gerber 4477 flatbed plotter	Proof Plot	0.3	1.0	Proof plots are initiated by the Cartographer.

PARTICIPANT No. 10 (1 model only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Autograph A7	Orientation Preparing & carring out	3	1.4	Operator Technologist level attained by 5 years on-job training.
Autograph A7 EK-8	Stereoplotting & Digitizing	3	1.4	ditto
Univac 90/70 262k byte	Programming & Editing	21	1.6	Programmer Technologist level attained by 5 years on-job training and 1 year formal training.
UNIVAC 90/70 262 k byte	Editing Magnetic tape recording to the specified format	3	1.6	ditto

REMARKS: Grid interval of DTM is 30 m.

PARTICIPANT No. 11

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Wild A10 Stereoplotter E.K.-8 Digitizer	Stereoplotting "Blind digitizing"	37		Photogrammetrist M. Sc. I.T.C.
PDP11/45 64K words hardware floating point processor. Vector general 3 DI refresh tube 1 RK05 disc 2 DEC tapes	Interactive Editing	2½		Geodetic engineer T.U. DELFT
I.B.M. 370/158	Transformation Stereomodel-terrain	2		Photogrammetrist M.Sc. I.T.C.
Zeta 3600A drumplotter on-line to I.B.M. 370/158	Test Plot	1		Operator Employment level attained by 8 years on the job training.
Coragraph, automatic Off-line plotter	Final Plot	1		

PARTICIPANT No. 12

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
A-INHOUSE				
1. Haag-Streit manual coordinatograph	1. Control Trace	3.0	1.67	Shift Supervisor 25 years in Cartography/photogrammetry
	1.1 Plotting of control values			
2. Wild A8-EK8 Facit Paper Tape Punch	2. Stereoplotting			
	2.1 Model Orientation	12.83	1.38	Photogrammetric Engineer 13 years in photogrammetry.
	2.2 Digitizing Detail	23.23	1.33	Senior Operator 14 years in Cartography/Photogrammetry.
	2.3 Digitizing Contours	26.94	"	
3. Honeywell 316 8K works Honeywell Paper Tape Reader (1000 ch/sec)	3. Computing			
	3.1 Correcting paper tape	1.50	1.52	Chief Computer. 30 years in Land Survey/Photogrammetry.
Facit paper punch (75ch/sec) Teletype (10ch/sec)	3.2 Transformation from model coordinates into ground coordinates.	16.00	1.0	Computing Technician. Degree in Geography. 3 yrs in Computing section of Air Survey Organization.
B-OUTSIDE BUREAU		Bureau Cost		
4. Computer Bureau CDC 6500 Disc and Mag tapes Paper Tape reader 300 (ch/sec)	4. Data Conversion 4.1 Conversion from paper tape to magnetic tape	55		Systems Advisor
5. Computing Bureau Offline Calcomp 936 Drum Plotter	5. Proof Plot			
	5.1 Production of Magnetic Tape	44		Systems Advisor
	5.2 Proof Plot	15		Machine Operator

PARTICIPANT No. 13

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Wild A-7 Stereoplotter EK-5 Digitizer	Stereoplotting "Blind Digitizing"	90	1.35	Photogrammetrist
PDP 11/45 - 45 K Memory 9 Track 800 Bpi Magnetic tape unit.	Interactive Editing	40	1.25	Computer Operator
Offline Avtomatic coordinatograph Coradomat K-21 Coradi	Proof Plot	2	1.0	Operator

PARTICIPANT No. 14

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Manual	Preparation	3	1.3	Photogrammetric technician with 4 years on-job training including 2 years day release leading to technician certificate.
		7	1.7	Photogrammetric technician with 7 years on job training.
		0.5	2.7	Senior photogrammetrist with 14 years' experience.
2 Wild A8 plotters with linear encoders in x and y and rotary encoder in z.	Stereoplotting Digitizing	44.5	1.3	Photogrammetric technician with 4 years on-job training including 2 years day release leading to technician certificate.
		15	1.7	Photogrammetric technician with 7 years on job training.
		7.5	2.7	Senior photogrammetrist with 14 years' experience.
PDP 11/50 DEC Computer with 96K 16-bit parity memory, 40 megabyte disc 2 x 9-track mag tape units, PTR, PTP & line printer	Data processing	2.35	2.3	Photogrammetrist/Computer Controller with 15 years' experience.

PARTICIPANT No. 14 (con't)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Ferranti EP 331 Flatbed plotter	Plotting checkplot	6.5	2.0	Photogrammetric Technician/ Computer operator with 14 years' experience.
Off instrument	Examining checkplot	6.5	1.3	Photogrammetrist with 4 years on-job training including 2 years day-release leading to ONC.
Ferranti EP 210 Freescan Digitizer	Editing	4	2.3	Photogrammetrist/Computer controller with 15 years' experience.
	Editing	4	2.0	Photogrammetric Technician/ Computer operator with 14 years' experience.
Ferranti EP 331 Flatbed Plotter	Plotting final plot	6	2.0	Photogrammetric Technician/ Computer operator with 14 years' experience.

PARTICIPANT No. 18 (2 models only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Zeiss Planicomp C-100 HP 21MX-E CPU 32K Memory Dual Disc Cartridge 9-Track 800 bpi Magnetic Tape Alphanumeric CRT Terminal	Stereoplotting	21.0	1.0	Cartographer level attained by 1 year formal training and 3 years on job training.
	On-line Data Editing	4.0	1.25	Photogrammetrist level attained by 2 years on job training.
(Off Line) Nihondenki MS CPU (Terminal of ACOS) 9-Track 800 Bpi MT Unit 9-Track 1600 Bpi MT Unit	Copy from 800 bpi to 1600 bpi mag tape	0.05	1.25	Photogrammetrist
(Off Line)) Nihondenki ACOS CPU -350K Memory 9 Track 1600 Bpi MT Unit	Editing for Calcomp	0.1	1.25	Photogrammetrist
(Off Line) Calcomp 748 Flat Bed Plotter	Proof Plot	0.1	1.25	Photogrammetrist

APPENDIX E

TIME COMPARISON

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT	DATA ACQUI-SITION (hours)	EDITING (hours)	REMARKS	COMMENTS
14	42	11	Blind stereodigitizing with spindle driven instruments (A-8). Editing with check plots and digitizer.	Complete data. Minor gaps. Essentially clean.
8	17.7	28	Blind stereodigitizing with hand driven instrument (PG-2). Editing with an interactive graphic system.	Completed data. Minor gaps and overlaps. essentially clean.
12	45.9	0	Blind stereodigitizing with spindle driven instrument (A-8), EK-8 and fast paper tape punch.	Same comments as large scale test.
6	20.3	6.3	Interactive stereodigitizing with spindle driven instrument (AM H). Editing with an interactive graphic system.	Same comments as large scale test.
15	16	-	Automatic heighting with B-8.	Elevations only (DTM and contours). - no planimetry.
16	87	18	Plotting of manuscript with spindle drive instrument (A-7) followed by digitizing of manus-cript on digitizer with paper tape unit.	2 models only. Planimetry only. Some houses missing. Point mode. Points are far apart.
17	19	0	Scanning of stereomodel with spindle driven instrument (Topocart-B) -No time reported for editing	1 model only. No planimetry -DTM only

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 6

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Manual	Set up models & determine model-ground coordinate reference.	5.5	1.0	Photogrammetrist technologist level attained by 6 years on-job training (DD5)
Wild AMH Stereoplotter with Cybernex D1600 Digitizer/ Terminal hardwired to M&S interactive graphic system	Interactive digitizing	20.3	1.0	"
consisting of PDP 11/45 with 128 K memory, 2 RP04 38 mB discs, Tektronix 4014/613 dual screen graphic station, TU 10/TM 11 tape drive. On-line Calcomp 960 drum plotter.	Interactive editing	6.3	1.0	"
Editing station on-line with above M&S system	Proof plots	1.0	1.0	"
	Processing data (format conversion from internal format to ISP tape format)	1.5	1.0	"

PARTICIPANT No. 8

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Kern PG-2 Stereoplotter Altek AC189 Digitizer	Stereoplotting Digitizing and simultaneous drawing of manuscript	17.7	1.35	Photogrammetric Technician with more than ten years of experience.
M&S Computing, Inc., System PDP-11/70 CPU-128K Memory Two 80 Megabyte Drives Three 800/1600 bpi Magnetic tape units	Interactive Editing	28.0	1.0	Cartographer/Photogrammetrist with more than four years of experience.
Offline Gerber 4477 flatbed plotter	Proof Plan	0.25	1.0	Proof plots are initiated by the Cartographer.

PARTICIPANT No. 12

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
A-INHOUSE				
1. Haag-Streit Manual Coordinatograph	1. Control Trace			
	1.1 Plotting of Control values.	4.0	1.68	Shift Supervisor 25 years in cartography/photogrammetry
2. Wild A8-EK8 Facit Paper Tape Punch	2. Stereoplotting			Photogrammetric Engineer 13 years in photogrammetry.
	2.1 Model Orientation	11.72	1.38	
	2.2 Digitizing Detail	29.63	1.33	Senior Operator 14 years in Cartography/photogrammetry
	2.3 Digitizing Contours	16.28	1.33	
3. Honeywell 316 8K words Honeywell Paper Tape Reader (1000ch/sec)	3. Computing			
	3.1 Correcting paper tape	2.00	1.52	Chief Computer.30 years in Land Survey/Photogrammetry
Facit Paper Tape punch (75ch/sec) Teletype (10ch/sec)	3.2 Transformation from model coordinates into ground coordinates	18.50	1.0	Computing Technician. Degree in Geography. 3 years in Computing Section of Air Survey Organisation
		Bureau Cost		
B-OUTSIDE BUREAU				
4. Computer Bureau CDC 6500 Disc and mag tapes Paper Tape Reader 300 (ch/sec)	4. Data Conversion			
	4.1 Conversion from paper tape to magnetic tape	46		Systems Advisor
5. Computing Bureau Offline Calcomp 936 Drum Plotter	5. Proof Plot Production of magnetic tape	36		Systems Advisor
	5.2 Proof Plot	10		Machine Operator

PARTICIPANT No. 14

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Manual	Preparation	3	2.9	Photogrammetric Superintendent with 15 years' experience
2 Wild A8 plotters with linear encoders in x and y and rotary encoder in z.	Stereoplotting Digitizing	18	1.59	Photogrammetric technician with 11 years' experience
		13	1.76	Senior photogrammetric technician with 12 years' experience
		11	1.0	Photogrammetric technician with 3 years on-job training including 2 years day release leading to technician certificate
PDP 11/50 DEC Computer with 96K 16 bit parity memory, 40 megabyte disc, 4 x 9-track map tape units PTR, PTP and line printer	Data Processing	2.75	2.3	Photogrammetrist/Computer controller with 15 years' experience
Ferranti EP 331 Flatbed Plotter	Plotting checkplot	3.5	2.0	Photogrammetric Technician/ Computer with 14 years' experience
Off Instrument	Examining checkplot	6.5	1.76	Senior photogrammetrist with 12 years' experience
Ferranti EP 210 Freescan Digitiser	Editing	4.5	2.3	Photogrammetrist/Computer controller with 15 years' experience
Ferranti EP 331 Flatbed Plotter	Plotting final plot	2.0	2.0	Photogrammetric Technician/ Computer with 14 years' experience

PARTICIPANT No. 15

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Wild B8 Stereomat Tri-axis locator Hardwired interface to PDP-40 mini-computer of 32 K core with one 9 track magtape unit and single disc of 2.4mB capacity	Digitization of regular D.T.M. On-Line edit on scan line basis. D.T.M. to magtape	4 models @ 4 hours per model 16	1.0	Technical Officer Grade 2 Photogrammetric Drafughting Certificate of 4 years part time study at technical college. 10 years experience
Minicomputer (Data General) Plotter possibly Calcomp 960 Further details unknown	Model joining, calculation of contours over joined surface and plotting onto stable based material	2	Not applicable See remarks	Not known

REMARKS: Model joins, contour calculations and contour plotting are all performed by one contractor in the private sector.

Cost per model is about A $ 50 or US $ 43.

PARTICIPANT No. 16 (2 models only, planimetry only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Wild A-7 Autograph	Stereoplotting	33.5	1.42	Photogrammetrist Technologist level attained by 5 years on-job training.
SSD Digitizer Paper Tape Unit	Manuscript Digitizing	53.5	1.0	Operator Technologist level attained by 2 years on-job training.
NEAC 2200-520B CPU-96KC Memory Computer 9 Track 800bpi Magnetic Tape Unit	Editing	18.0	1.42	Operator Technologist level attained bv 2 years formal training in tech. college and 4 years on-job training.
Off-line Drastem-5000 AUTO DRAFTER	Proof Plot	0.5	1.0	Operator Technologist level attained by 2 years on-job training.

SMALL SCALE TEST - WEST BLOCK

PARTICIPANT No. 17 (1 model only)

EQUIPMENT RESOURCES	PROCESS	TIME (Hours)	UNIT WAGE	MANPOWER RESOURCES
Topocart-B LITAB NC-1000EK (Zeiss,Jena)	Stereoplotting Scanning and Digitizing	19	1.3	Photogrammetrist Technologist level attained by 5 years on-job training.
TOSBAC-3400 cpd-65KW Memory Disk Cartridge 9 Track 800 Bpi Magnetic Tape Unit	Off-line Data Editing	5	1.3	ditto

REMARKS: Proof plotting was not carried out.
Terrain surface were scanned at an interval of 1 mm on photographs.

APPENDIX F

COMPUTER TIME AND CORE REQUIREMENTS

The processing of the digital data was carried out on IBM 370/3032. The following gives the computer time and core requirements for the three groups of programs used in the test: those to test height accuracy, those to test line planimetry accuracy, and those to test point planimetry accuracy. All the programs were compiled with the FORTRAN IV EXTENDED compiler with maximum optimatization. We should note that core requirements given here include spaces needed by both program and data. There are about 3000 lines of code produced for the test programs.

(a) Summary of time and core requirements for testing height accuracy

No. of points (n) defining all contours in the participant's map	Core Requirement (K bytes)	CPU time Requirement standard pts. tested/second
60 000	Decreases from 704	2.5
35 000	to 448 with n.	4.0
20 000		7.0
15 000		7.5

(b) Summary of time and core requirements for testing line features

No. of points defining all line features in the participant's map	Core Requirement (K bytes)	CPU time Requirement standard segments tested/second
40 000	1024	0.5
20 000	1024	0.8
25 000	1024	1.0
2 500	1024	3.0

(c) Summary of time and core requirements for testing point features

No. of points defining all point features in the participant's map	Core Requirement (K bytes)	CPU time Requirement standard points tested/second
4 000	256	25
3 500	256	28
1 000	256	50
50	256	330