THE ALBERTA DIGITAL ELEVATION MODEL

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ABSTRACT

An account is given of the experience gained during the last four years of photogrammetric data capture of a digital elevation model for the province of Alberta. Methods are described and statistics are given for accuracy, data volumes and computing times. The Wild CIP program is used by the photogrammetric contractors and SCOP is used by the provincial government for data banking and data distribution. Contour output from each program is very similar. A three dimensional weeding program is used to reduce data along breaklines. The D.E.M. process is considered to be a routine production process and efforts are now being directed to landform modelling for various applications.

INTRODUCTION

The digital elevation modelling (D.E.M.) technique is now in general use in Alberta following testing of the process by private companies in 1981. All photogrammetric data capture for the Alberta Provincial government is performed under contract by three Alberta based companies. The companies now prefer to use the D.E.M. process and the Wild CIP program for the majority of their photogrammetric contouring contracts both for government and for private clients, such as mining companies. It should be noted that the contractors use seven Wild analytical stereoplotters for data capture. The non-government work is typically for volume measurement and contour interpolation for open-pit mining operations.

The title of this paper refers to the creation of a digital elevation model of the 650 000 sq. km. of the province as part of a digital mapping program at a nominal scale of 1:20 000. This project is now in its fifth year of production. The terrain varies from flat prairie to heavily dissected valleys and includes the foothills of the Rocky Mountains and northern muskeg swamps and forests.

PRODUCTION METHODOLOGY

Type of Data

The D.E.M. data is composed of mass points, breaklines and characteristic spot heights. The mass points are observed along parallel profiles and may or may not be in a grid pattern. Breaklines are classified as breaklines sharp and breaklines round. The former are edges of interpolated surfaces and when used in contour interpolation they produce a sharp jog in the contour. The breaklines round are used where extra information is needed but where a sharp contour jog is not required. The characteristic spot heights are observed on hill tops, depressions, saddles, water surfaces, and road intersections.

Data Capture Procedures

Seven Wild analytical stereoplotters are used for the observation of the D.E.M. from 1:60 000 aerial photography in order that 10 metre contours can be interpolated. Government does not specify the instrumentation, data density or computing procedure. The photogrammetric operator can see the terrain and should be the judge of where to place the observations to best describe the terrain surface. Data density for mass points ranges typically between 1.6 mm and 2.3 mm at photo scale. The measurement time averages 1.5 seconds per mass point. The time varies according to the clarity of the aerial photography and the vegetation cover. The stereoplotter operator who has plotted contours for several years does not immediately know where to observe D.E.M. data in order to produce a surface from which contours can be interpolated which correctly describe the terrain. He has to be trained by giving him interpolated contour plots so that he can see the result of his work. For this reason it would be preferable to have fast interpolation of a patch of D.E.M. data and immediate presentation by superimposition in the stereoplotter optics.

Breaklines enable fewer mass points to meet a specified surface accuracy and they enable contours to be produced which are cartographically more acceptable. Figures I and 2 show a typical 1:20 000 contour file and the detailed breaklines necessary in a dissected drainage area. However, breaklines are time consuming, both in the time taken to decide where to observe them and in their actual observation. Experience has shown that it is easier to allow the observation of more points than necessary rather than the careful and time consuming selection of the essential points. A 3D weeding program is used to reduce the number of breakline points.

Procedures have been tested for the use of test profiles in order to determine the optimum grid sampling density in a working area (see [1].). The contractors have not adopted the procedure as they consider that the selection of the location for the test profile within the stereo-model is also subjective. Although analytical stereoplotters are used, the progressive sampling method available with the equipment is not used and is considered slow.

Data Processing Procedures

The contractors use the Wild CIP Program to process the D.E.M. surface and interpolate the 10 metre contours. The objective is to prepare an ASCII file of D.E.M. data together with a file of contours and spot heights to be shown on the final 1:20 000 map. The latter is edited on an interactive graphics system. Software has been written to check for crossing breaklines (most often due to miscoded breakline points).

The Land Information Services Division has used the Stuttgart Contour Program SCOP since 1985 for the creation of a variable grid file plus breaklines from the contractors' data. The 25, 50 and 100 metre grids are interpolated according to the curvature of the surface. In this way the flatter prairies have a 100 m spacing and the more dissected surfaces, a 25 or 50 metre grid. Figure 3 illustrates the variable grid. The SCOP binary file is stored and the ASCII variable grid plus breaklines is prepared upon demand for distribution to users. A 200 metre computing unit is used and overedge data is used within 500 metres of the map sheet edge. The process of creating the overedge requires that the surrounding eight map sheets are used to abstract the overedge data.

The 3D weeding program for generalization of breaklines, as used by the provincial government, uses the Douglas-Poiker algorithm to identify every significant breakline point which falls outside of the planimetric tolerance band of 2.3 metres. The elevations of data points which have not been identified as significant in the planimetric filter are then interpolated from the elevations of the first significant points which preceed and follow the point value to be interpolated. When the difference between interpolated and actual elevation values exceed the vertical tolerance value of 1.3 metres then the points will be retained. A 3D distance of 100 metres is used as a maximum value between retained points. This tolerance can also be used to find breaklines where the stereoplotter operator has forgotten to code the end of one line and the start of another.

Approximately 10% of the map sheets are checked by producing SCOP contours and overlaying the CIP contours. The agreement is usually excellent even in flat areas - possibly due to the observed data points being close together ie. 5 to 7 mm at 1:20 000.

D.E.M. Database

SCOP is used to create a D.E.M. database by producing a variable grid with breaklines and storing a binary file. Exclusion lines in the form of closed polygons are created around lakes. Each D.E.M. file carries a file header with eighteen items, these include date of photography, photo scale, accuracy estimator, dates of compilation and computation and minimum and maximum Z values. The SCOP variable grid file contains approximately five times as many points as the contractor's data file. Tree boundaries are not captured as part of the 1:20 000 mapping, otherwise two classes of D.E.M. points could be classified - those of a lower accuracy falling within tree polygons and those of standard accuracy in open country. This process is used in the provincial government urban mapping program. (See [2]).

PRODUCTION STATISTICS

Data storage volumes:
For one 1:20 000 map sheet of 16 km by 14 km:-

SCOP input ASCII file	1.4 mega bytes
SCOP input binary file	0.7 mega bytes
Contour plot binary file	0.8 mega bytes
Scratch working binary file	1.4 mega bytes
Variable grid binary file	0.7 mega bytes
Typical total working file	5.0 mega bytes

Computing time on VAX 785:-

Weed breaklines	2 CPU minutes
Transform to SCOP ASCII	3 CPU minutes
Read 8 surrounding files for overedge	14 CPU minutes
SCOP input	4 CPU minutes
Create variable grid	58 CPU minutes
Create plot file	4 CPU minutes
Total	85 CPU minutes

DEM observations:-

Regular grid (mass points)	16 100
Additional random points	6 900
Breakline points	10 056
Total Observations	33 056
SCOP variable grid points:	175 182

Accuracy:

Project specifications require that 90% of the D.E.M. observations should be within 3 metres of reobserved values measured with the same diapositives in a Wild AC1 stereoplotter. The interpolated surface, and so data density, is checked by requiring 90% of reobservations along contours should be within 5 metres of the contour value.

Tests with a helicopter borne laser profiler indicated that in an area of trees ranging from 10 to 15 metres tall the D.E.M. surface was biased high by 2.4 metres with a standard deviation about that mean of 1.8 metres. (See [2]).

Costs:

The contractors consider that the D.E.M. procedure with Wild TA2 scribing of contours is now cheaper than conventional photogrammetric contouring and manual scribing.

APPLICATIONS

D.E.M. files are being distributed for a variety of applications. Those include interpolation of profiles for planning pipeline and transmission line routes, soil erosion studies, slope and aspect for forestry, prediction of forest fire tower view coverage, oil company usage for definition of the upper surface of geological models, correction for satellite imagery. We anticipate that government will make use of the data for planning studies for water reservoir location.

Land form modelling using derivatives of the D.E.M. can be used for checking the D.E.M. as well as for generating watershed diagrams and the slope and aspect already mentioned. Work is continuing at the University of Alberta under the direction of Dr. R. Eyton (see [3]) and Figure 6 illustrates the potential for the automatic detection of blunders and poor D.E.M. observing practices. The figure shows the use of Laplacian Curvature analysis to illustrate a bad model join and systematic errors in data collection. White patches are convex and dark patches are concave.

The perspective view of the variable grid shown in Figure 4 is useful in communicating planning concepts between everyday users of the D.E.M. output. The concept of draping the 1:20 000 2D planimetric graphics files eg. roads, rivers, over the D.E.M. for display or for the derivation of full 3D graphics if needed has been successfully used.

The D.E.M. files have been used within the Mapping Branch for the derivation of a 200 metre D.E.M. spacing from the SCOP variable grid file. Sixty four 1:20 000 files comprise one 1:250 000 map sheet and Figure 5 shows a portion of the derived 1:250 000 map sheet to scale. The 20 metre contours were interpolated without further generalization from the 200 metre grid. The 1:250 000 covers over 15 000 sq. km. and 456 000 data points were used. The sixty four 1:20 000 files each had overedge points which were not removed from the computations. File sizes and computer times follow:

64 SCOP binary files	30 megabytes
64 (200 m.) ASC11 files	39 megabytes
64 (200 m.) ASC11 files without breaklines	19 megabytes
64 files merged into one ASC11	19 megabytes
SCOP input binary	7 megabytes
SCOP scratch files	43 megabytes
SCOP 2 (200 m) grid file, binary	4 megabytes
Plot file	2 megabytes
Total	163 megabytes

CPU times, VAX 785:-

Binary to ASC11, 64 files		128 mins CPU
Extract breaklines		23 mins CPU
Appending files to create one		4 mins CPU
SCOP input		35 mins CPU
Create 200 m grid file		74 mins CPU
Create plot file		58 mins CPU
	Total	322 mins CPU

Small contour isolations which are inappropriate for a 1:250 000 scale map sheet can be removed by software. Crowding of some contours will require further generalization.

CONCLUSIONS

The D.E.M. process is now an everyday production procedure within the surveying and mapping community in Alberta. Users are becoming more familiar with the potential of the D.E.M. data and plans to complete the total coverage of the province in the early 1990's will raise the users' interest. Data capture systems are required which enable the stereoplotter operator to quickly check the validity of his D.E.M. data surface by superimposition of the data and interpolated contours with the stereomodel. This procedure will also enable revision of the surface to take place. The combination of an accurate D.E.M. and 2D graphics planimetric mapping files is more powerful than a 3D graphics planimetric file plus contours as the latter approach lacks the usefulness of the DEM file with breaklines.

ACKNOWLEDGEMENTS

Dan Reiners prepared the figures 1-5 and statistics for this paper and is responsible for the creation of the SCOP database.

Valerie Johnson prepared figure 6 and is assisting in the application of land form modelling in the Land Information Services Division.

The D.E.M. observations are carried out under contract by:
The Orthoshop - Calgary, Alberta
Stewart, Weir Land Data Inc. - Edmonton, Alberta
Western Photogrammetry Divison, Underwood McLellan Ltd. - Edmonton, Alberta

REFERENCES

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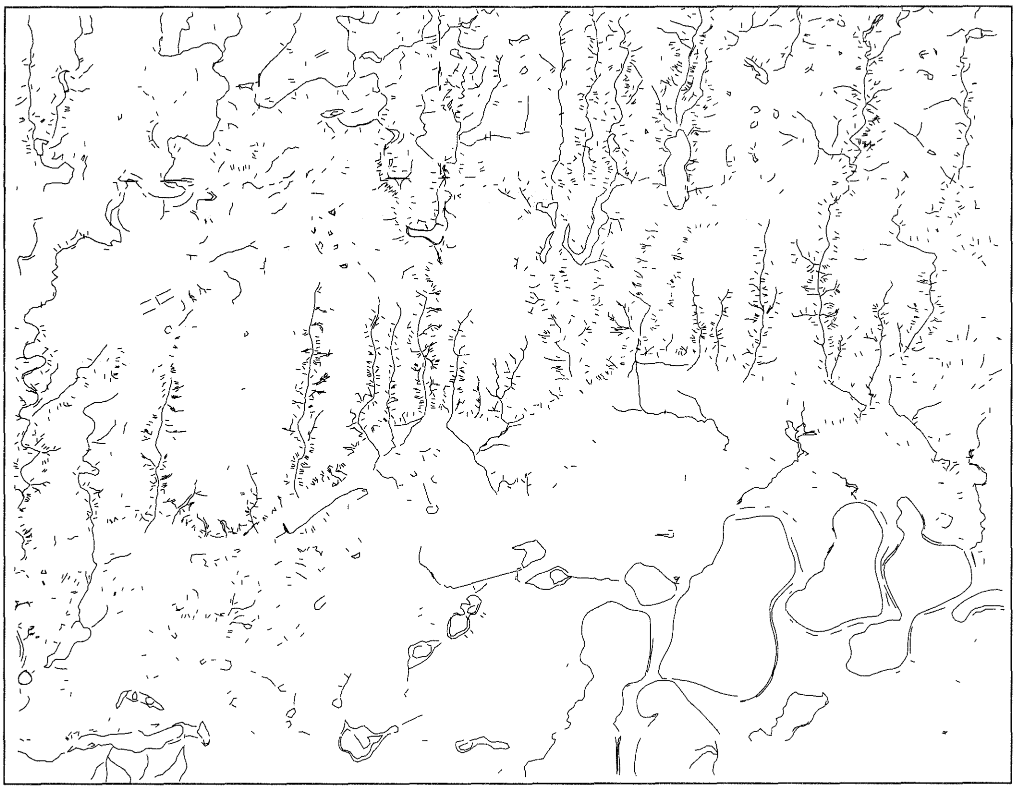
[2] Toomey, M.A.G., March 1986 ASPRS Proceedings, Digital Elevation Models in Alberta.

[3] Johnson, Valerie, April 1988 Masters thesis University of Alberta, Department of Geography, An Evaluation of Digital Terrain Modelling for Terrain Analysis Applied to the Alberta 1:20 000 Digital Mapping Project.

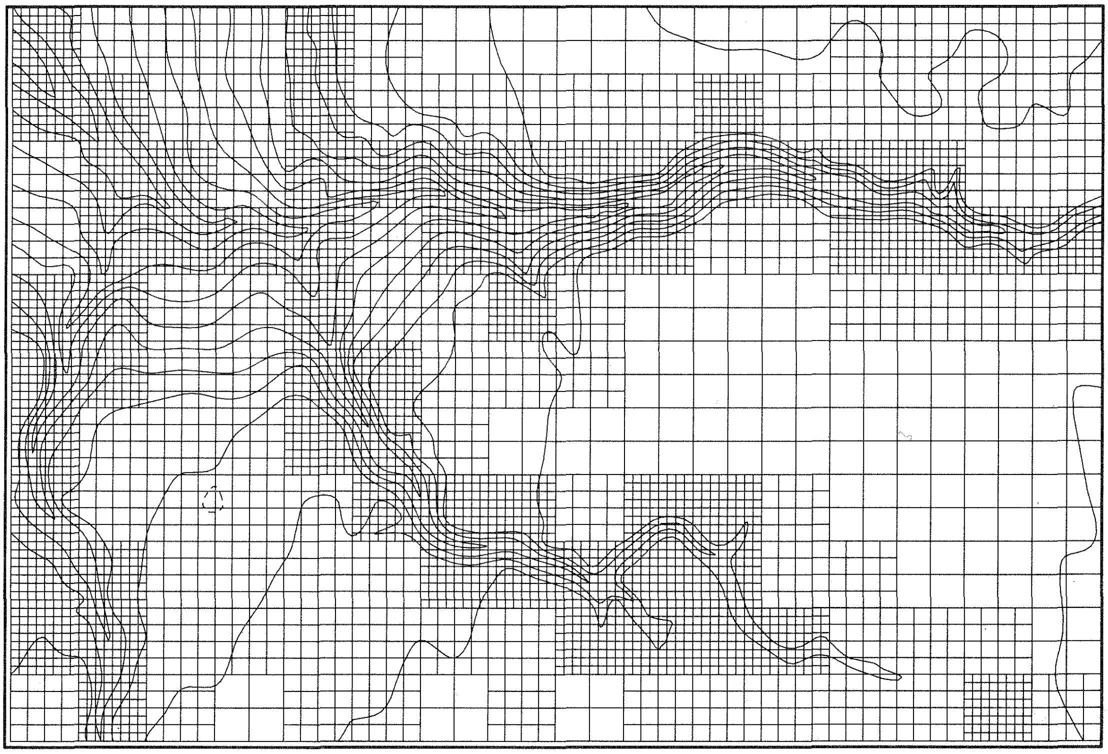
1:20 000 10 M CONTOUR INTERVAL

Figure 1



1:20 000 BREAKLINES

Figure 2



TOP VIEW OF VARIABLE GRID (25, 50, 100 M INTERVALS) WITH CONTOURS.

Figure 3

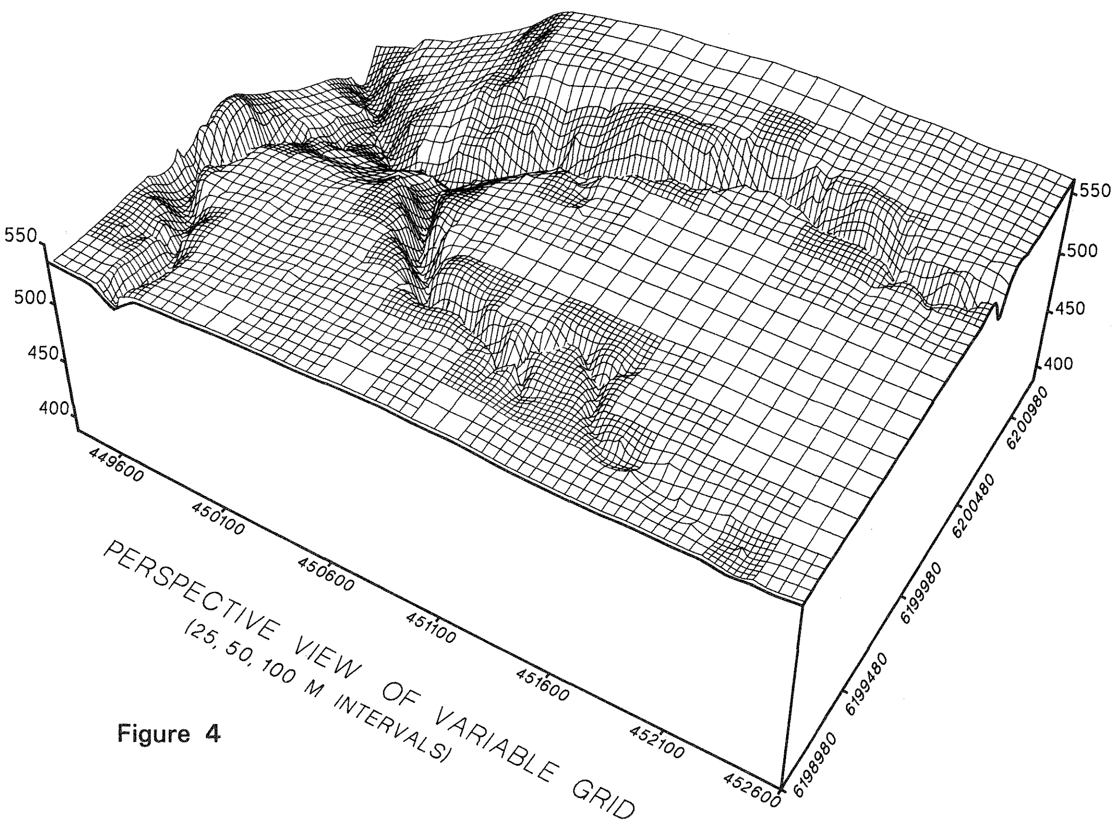


Figure 4

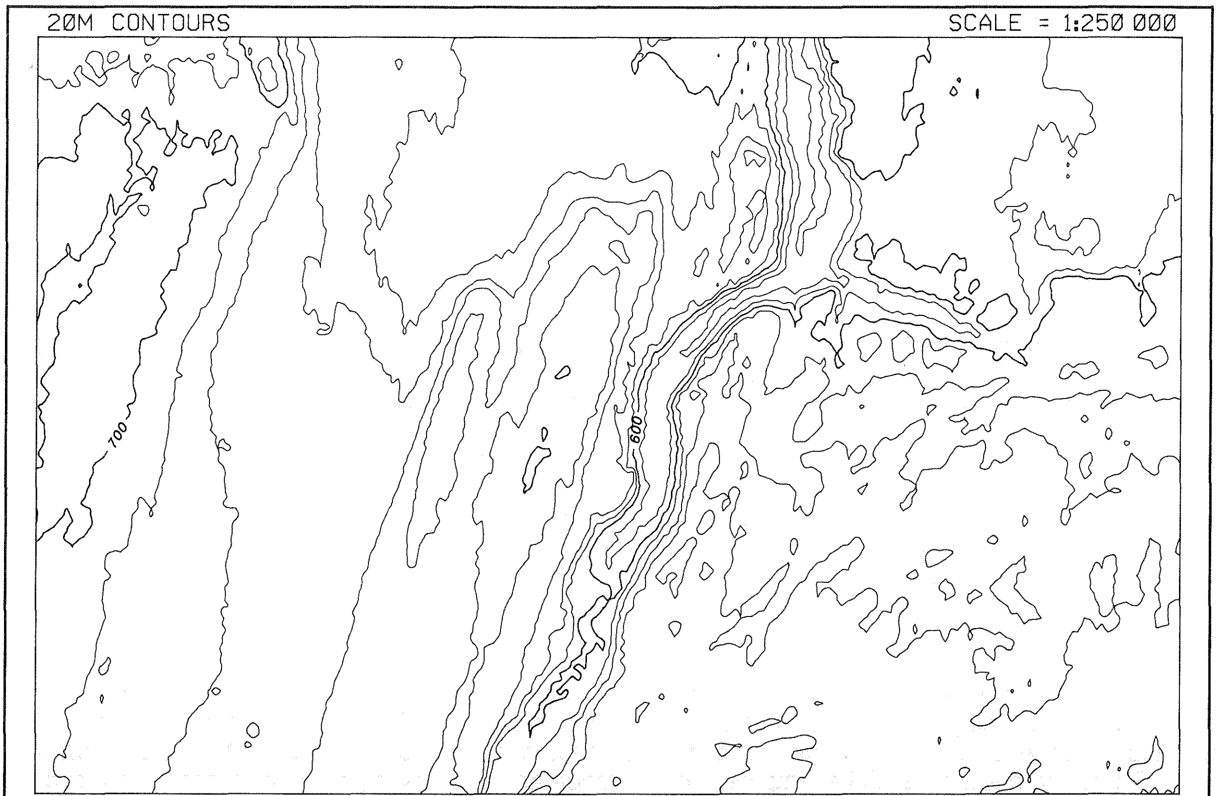


Figure 5

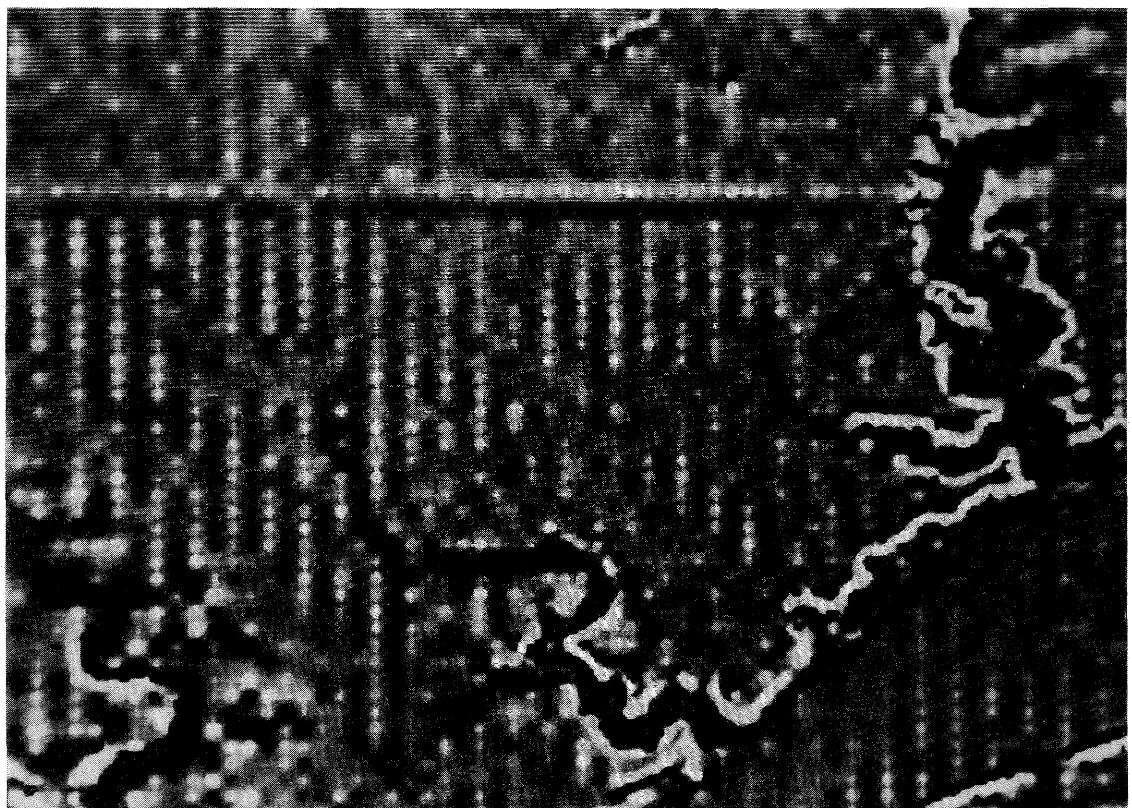


Figure 6

Produced by Provincial Mapping Section, Land Information Services Division 1988