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A METHOD FOR THE PROCESSING AND ANALYSIS
OF DIGITAL TERRAIN ELEVATION DATA

by

Bobby G. Junkin

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A METHOD FOR THE PROCESSING AND ANALYSIS
OF DIGITAL TERRAIN ELEVATION DATA

By Bobby G. Junkin*

SUMMARY

This report presents a method for the processing and
analysis of digital topography data that can subsequently
be entered in an interactive data base in the form of slope,
slope length, elevation and aspect angle. Included are a
discussion of the data source and specific descriptions of
the data processing software programs. In addition, the
mathematical considerations involved in the registration of
raw digitized coordinate points to the UTM coordinate system
are presented. Scale factor considerations are also included.
Results of the processing and analysis are illustrated using
the Shiprock and Gallup Quadrangle test data.

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<tr>
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</tr>
<tr>
<td>CCT</td>
<td>Computer Compatible Tapes</td>
</tr>
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</tr>
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</tr>
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<tr>
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<tr>
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</tr>
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INTRODUCTION

Land resource managers are becoming increasingly aware of the problem of converting disparate sources of data in map format into a form suitable for processing on a computer-oriented information system. This information, acquired from map sources or remote sensor data obtained from aircraft and satellites, is compiled into data bases which contain information on land use, topography, soil, rainfall, population density, etc. This report defines the procedures and techniques in use at the NASA/ERL for processing digital topography data that can subsequently be entered in a data base in the form of slope, slope length, elevation and aspect.

DIGITAL TERRAIN ELEVATION DATA

The National Cartographic Information Center (NCIC) of the U. S. Geological Survey, Department of the Interior, provides a national information service to make cartographic data of the United States available to the public and to various federal, state, and local agencies (reference 1). These cartographic data include standard 9-track 800 BPI or 1600 BPI computer-
compatible tapes (CCT) which contain digital representations of terrain elevations. These tapes, which are produced by the Defense Mapping Agency Topographic Center (DMATC) from the 1:250,000-scale series of maps, are copied and distributed to users by the NCIC.

The DMATC utilizes a processing system which collects data from a 1:250,000-scale map using digital graphic recorders tied into a central processor with disk storage, magnetic tape output and verification plot capability. The function of this system is to generate a magnetic tape file containing a matrix of elevation readings extracted at 250 micrometer intervals. The 1:250,000-scale map generally covers one by two degrees of longitude and latitude. The DMATC prepares two one-degree by one-degree matrices for each quadrangle. Each block of data is stored on a 7-track UNIVAC 1108 computer tape by the DMATC and forwarded to the NCIC. The NCIC subsequently takes these data and stores up to eight one-degree quadrangles of longitude and latitude on each 9-track (1600 BPI) tape (four using 800 BPI tapes). This latter data format is generally used by the ERL as its source of topographic information.

General information concerning the source of data is given in Appendix D.
DATA PROCESSING SOFTWARE DEVELOPMENT

General Program Functions

The NASA/ERL software programs for geographical data analysis and display consist of four separate programs for processing digital terrain data tapes produced by the DMATC. These programs perform the following functions: (1) Transforms data in the local \((\bar{x}, \bar{y})\) digitizer system to the \((X_E, Y_N)\) UTM system, (2) translates the \(1^\circ \times 1^\circ\) data set to an input origin, (3) adjusts the input data set to any desired output cell size, (4) computes slope, slope length, and aspect for each cell by use of the maximum gradient from a center cell to the surrounding eight cells, (5) generates output data files (elevation, slope, slope length, and aspect) which are in a form suitable for entering into the ERL Interactive Data Base Display Program (IDDP).

Specific Program Descriptions

The processing of digital terrain tapes requires the execution of four separate programs. These programs are described herein.

Program TOPREF. This program prints out pertinent information for each column of data as written to the reformatted output tape. The starting \(x-y\) points, ending \(y\)-point, number of \(y\)-points, and the first three and last three elevation data values are printed for each \(x\)-column. Also, the minimum and maximum elevation values are printed. This program reads the NCIC data tapes of 15840-word records (16-bit words) and writes a tape file of 2005-word records in the following format:
word 1 = 0
word 2 = record number
word 3 = \( x \) coordinate in .01 inches for this record
word 4 = starting \( y \) coordinate in .01 inches
word 5 = \( N \) = number of elevation values in this record
words 6 through \( (6 + N) \) = elevation values of points 
\((\bar{x},\bar{y}_1)\) through \((\bar{x},\bar{y}_N)\)
words \((6 + N + 1)\) through 2005 = zero fill

**Program TOPTWO.** This program prints out all input control parameters which define the area of interest to process, column and row bias's, etc. Also printed out is a table of computed easting and northing and elevations for the first and last data point for each row. The reformatted tape from TOPREF is read. Card input control parameters are used to extract only that data required for processing the selected area and writes out a file suitable for sorting. Output from this program consists of 7200-word records in 3-word groups of \( X_E \) and \( Y_N \) coordinate values for each cell and its elevation value.

**Program TOPSRT.** This program prints out check point row numbers for raw data that are sorted and output in reverse order. The data that are written in TOPTWO are sorted so that all elevation values corresponding to \( Y_N \) are written as the first record, those elevation values corresponding to \( Y_{N+1} \) as record 2, etc., continuing on until record \( N = \) all elevation values corresponding to \( Y_1 \). These data are written to an intermediate scratch disk file, and then output to tape.
Program TOPODB. This program prints input control parameters and input levels for elevation and slope. Optionally, a printer map is printed showing coded levels for each data element in row-column format for all four types of output. Output consists of four files of data to disk for input to the IDDP:

1. Elevation data
2. Slope data
3. Aspect data
4. Slope length data

MATHEMATICAL ANALYSIS

UTM Coordinate Equations

Consider the example of a 1:250,000-scale map as shown in figure 1. The UTM \((X_E, Y_N)\) grid system on these type maps is not normally aligned with the \((\tilde{x}, \tilde{y})\) coordinate system of the digitizer system. Thus, an angle correction is required for each \(1^\circ \times 1^\circ\) area or file of data. The sheet corners indicated by the arrows are translated into the origin of the data file by the following:

\[
\begin{align*}
\tilde{x}_i' &= \tilde{x}_i - \tilde{x}_{\theta RI} \\
\tilde{y}_i' &= \tilde{y}_i - \tilde{y}_{\theta RI}
\end{align*}
\]

where:

\((\tilde{x}_i, \tilde{y}_i) =\) plate coordinates of digitizer points, in inches
\((\tilde{x}_{\theta R1}, \tilde{y}_{\theta R1})\) = coordinates of SW sheet corner of file 1, in inches

\((\tilde{x}_{\theta R2}, \tilde{y}_{\theta R2})\) = coordinates of SE sheet corner of file 2, in inches

The \((\tilde{x}_i', \tilde{y}_i')\) data are corrected for the \(\Delta\) angle between the polyconic coordinate system and the UTM coordinate system to yield corrected \((\tilde{x}_i'', \tilde{y}_i'')\) digitizer plate points.

The relationship between the corrected digitizer plate points and the corresponding UTM coordinates are given by the following transformation:

\[
X_{Ei} = \tilde{x}_i'' S_{Xi} + X_{\theta RJ} \tag{2}
\]

\[
Y_{Ni} = \tilde{y}_i'' S_{Yi} + Y_{\theta RJ} \tag{3}
\]

where \(J = 1, 2,\) and:

\((X_{\theta RJ}, Y_{\theta RJ})\) = UTM coordinates of SW or SE sheet corner

\(S_{Xi}\) = X scale factor, file 1 or 2

\(S_{Yi}\) = Y scale factor, file 1 or 2

It should be pointed out that the above equations, in effect, register the plate coordinates of the left side 1° x 1° area of a quad map to the SE sheet corner and the subsequent UTM coordinates are merely determined with respect to the \((X_{\theta R2}, Y_{\theta R2})\) origin of the SE sheet corner.

**Derivation of Equations for Data Registration**

The \((\tilde{x}, \tilde{y})\) digitizer plate coordinate points are registered to the UTM coordinate system through the utilization of the \(\Delta\) angle between the polyconic coordinate system and the UTM coordinate system. Consider first the geometry in figures 2 and 3. These figures depict the location situations that are
Figure 2. East of Zone CM
possible regarding a quad sheet relative to the central meridian of a zone. Figures 4, 5, 6, and 7 show the geometry between the $(x, y)$ coordinate system and the UTM coordinate system.

We first consider the geometry in figure 4 as relates to the right side of a quad located east of the zone CM. From this figure:

\[ \hat{y}'' = a_1 + b_1 \tag{4} \]

and:

\[ \hat{x}'' = a_4 \cos A \tag{5} \]

\[ a_1 = a_4 \sin A \tag{6} \]

from $\Delta T_1$:

\[ \hat{y}' = b_1 \cos A \tag{7} \]

\[ b_3 = b_1 \sin A \tag{8} \]

solving (7) for $b_1$:

\[ b_1 = \frac{\hat{y}'}{\cos \Delta} \tag{9} \]

substituting (9) in (8):

\[ b_3 = \frac{\hat{y}' \sin \Delta}{\cos \Delta} \tag{10} \]

also:

\[ a_4 = \hat{x}' - b_3 \tag{11} \]

substituting (10) in (11):

\[ a_4 = \hat{x}' - \frac{\hat{y}' \sin \Delta}{\cos \Delta} \tag{12} \]
Figure 4. East of Zone CH, Right Side of Quad
and (12) in (5):

\[ \tilde{x}'' = \tilde{x}' \cos \Delta - \tilde{y}' \sin \Delta \]  

(13)

substituting (12) in (6) and the result in (4) and also (9) in (4) yields:

\[ \tilde{y}'' = \tilde{x}' \sin \Delta - \frac{\tilde{y}' \sin^2 \Delta + \tilde{y}'}{\cos \Delta} \]  

(14)

where the \((\tilde{x}, \tilde{y})\) points are translated to the \((x_o, y_o)\) origin point by:

\[ \begin{align*}
\tilde{x}' &= \tilde{x} - x_o \\
\tilde{y}' &= \tilde{y} - y_o
\end{align*} \]  

(15)

Thus, equations (13) and (14) give the registration of the \((\tilde{x}, \tilde{y})\) plate coordinate point relative to its \((\tilde{x}'', \tilde{y}'')\) position in the UTM coordinate system. These equations are valid for the right side of a quad map and east of the zone CM.

Consideration of the geometry in figure 5 yields the following equations for the left side of a quad map, east of zone CM:

\[ \begin{align*}
\tilde{x}'' &= \tilde{x}' \cos \Delta + \tilde{y}' \sin \Delta \\
\tilde{y}'' &= -\tilde{x}' \sin \Delta - \frac{\tilde{y}' \sin^2 \Delta + \tilde{y}'}{\cos \Delta}
\end{align*} \]  

(16)

These equations are also valid for the right side of a quad, west of the zone CM. This can be verified by consideration of the geometry in figure 6. Consideration of the geometry in figure 7 also shows equations (13) and (14) to be valid for the left side of a quad map, west of the zone CM.
Figure 5. East of Zone CM, Left side of Quad

\( (x_0, y_0) \): SE sheet corner

\( c_3 = \tilde{y} + c_1 \)

\( \Delta \)

\( \Delta \)

\( \tilde{x} \)

\( \tilde{y} \)

\( \tilde{y}' \)

\( \tilde{y}'' \)

\((x, y)\)

\((x_0, y_0)\)

\( (0, 0) \)

\( \tilde{x} \)

\( \tilde{y} \)
Figure 6. West of Zone CM, Right Side of Quad
(x₀, y₀): SE sheet corner

Figure 7. West of Zone CM, Left Side of Quad
Scale Factor Equations

The equations for the \( \ddot{x} \) and \( \ddot{y} \) scale factors \( S_{X_i} \) and \( S_{Y_i} \), respectively, are derived by assuming that the scale factor varies linearly from the bottom to the top for \( \ddot{x} \) and from left to right for \( \ddot{y} \). For example, we can compute from known data \( \ddot{y} \) scale factor on the left, \( S_{Y_L} \), and a \( \ddot{y} \) scale factor on the right, \( S_{Y_R} \). The \( \ddot{x} \) position of these scale factors are known data points \( \ddot{x}_L \) and \( \ddot{x}_R \). On the basis of the linearity assumption, we can write the general equation:

\[
S_{Y_i} = m_Y \ddot{x}_i + b_Y
\]  

But the two end conditions yield:

\[
m_Y = (S_{Y_R} - S_{Y_L}) / (\ddot{x}_R - \ddot{x}_L)
\]

\[
b_Y = S_{Y_L} - m_Y \ddot{x}_L
\]

Similarly for \( S_{X_i} \):

\[
S_{X_i} = m_X \ddot{y}_i + b_X
\]

Here the two end conditions yield:

\[
m_X = (S_{X_T} - S_{X_B}) / (\ddot{y}_T - \ddot{y}_B)
\]

\[
b_X = S_{X_B} - m_X \ddot{y}_B
\]

Slope, Slope Length, and Aspect Determination

Thus, equations (2) and (3) yield an \((X_{E_i}, Y_{N_i}, Z_i)\) type point for each plate coordinate point. If the output cell size
is greater than the input cell of .01" x .01" (208' x 208'), then the average of all the Z's in the output cell domain is computed and used as the Z value for the cell size.

For purposes of output and for subsequent entry into the data base, a column and row number for each point is computed from:

\[
\begin{align*}
  C.N. &= \left( \frac{X_E - X_\theta}{C_\theta} \right) + 1 \\
  R.N. &= \left( \frac{Y_N - Y_\theta}{C_\theta} \right) + 1
\end{align*}
\]

where:

\( C_\theta \) = output cell size

\((X_\theta, Y_\theta)\) = origin of output area, in meters

Consider the following figure 8:

![Figure 8. - Neighborhood cell approach.](image)
Slope is defined as $|\Delta H| / \Delta D$, i.e.:

\[
S_1(P_5P_1) = (Z_5 - Z_1) / \sqrt{\Delta X^2 + \Delta Y^2}
\]

\[
S_2(P_5P_2) = (Z_5 - Z_2) / (X_2 - X_1)
\]

\[
S_3(P_5P_3) = (Z_5 - Z_3) / \sqrt{\Delta X^2 + \Delta Y^2}
\]

\[
S_4(P_5P_4) = (Z_5 - Z_4) / (Y_2 - Y_1)
\]

\[
S_5(P_5P_6) = (Z_5 - Z_6) / (Y_3 - Y_2)
\]

\[
S_6(P_5P_7) = (Z_5 - Z_7) / \sqrt{\Delta X^2 + \Delta Y^2}
\]

\[
S_7(P_5P_8) = (Z_5 - Z_8) / (X_3 - X_2)
\]

\[
S_8(P_5P_9) = (Z_5 - Z_9) / \sqrt{\Delta X^2 + \Delta Y^2}
\]

The largest $S_i$ ($i = 1, 2, \ldots, 8$) is selected as the slope of the cell containing $P_5$. The $Z_5$ value and the $Z_i$ corresponding to the largest $S_i$ are then compared. Then the aspect is defined as the direction from the smallest $Z$ to the largest $Z$.

Slope length is given by the following equation:

\[
S.L. = \sqrt{2(C_6)^2 + \Delta Z^2}
\]  \hspace{1cm} (25)

Since the slope and aspect determination are based on a neighboring approach, the perimeter cells for the adjacent files of a quad map are duplicated for use in the algorithm. This assures perimeter values for the slope and aspect of a $1^\circ \times 2^\circ$ area at the tape file interfaces.
RESULTS

Shiprock and Gallup Quad Data

The digital terrain data for the Shiprock and Gallup Quad, located as shown in figure 9, were selected for processing and for subsequent entry in the IDDP. The cross-hatched area in this figure represents the area of interest. Input parameters such as desired output origin, cell size, quantum levels for elevation, and slope were determined. Figure 10 shows a typical computer printout for one of the variables (topographic elevation) in the data base. The input data for the example shown in figure 10 is given in table I. The input indicates 241 rows and 354 columns of output, but only 62 rows and 120 columns are shown for the sake of brevity. Each letter represents a cell 100m x 100m in size. Each cell is identified by a row and column number and can be related back to the UTM coordinate system by equation (23). It should be pointed out that the \((x_0,y_0)\) origin is referenced to the lower left-hand cell corner.

To determine the magnitude of agreement between the actual data and data produced from the TOPO program, the elevation data for these files were aligned with the corresponding Landsat scene data. Specific mountain peaks and/or features for the file 2 data were then identified from a 1:62,500-scale USGS map. A northing, easting, and elevation value were read from the map for three specific points. The northing and easting of each
Figure 9. Shiprock and Gallup Quad Data, RCC 135
TABLE I.- INPUT DATA FOR EXAMPLE SHOWN IN FIGURE 10

<table>
<thead>
<tr>
<th>Level</th>
<th>ST. EL.</th>
<th>END EL.</th>
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<td>1</td>
<td>A</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>6000.0</td>
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<td>3</td>
<td>C</td>
<td>6100.0</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>6200.0</td>
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</tbody>
</table>
point were then used to compute a row and column number and the corresponding elevation interval was determined from the TOPO output data. This comparison is shown in table II and shows close agreement between the actual data and the data produced as output from the TOPO programs.

As a further accuracy evaluation, the four known sheet corners for files 3 and 4 of the RCC 135 data and file 3 of the RCC 136 data were translated and registered to the UTM coordinate system using equations (2) and (3). These UTM values were then compared with the known UTM values and the differences recorded as shown in table III.

**CONCLUDING REMARKS**

The NASA/ERL has developed a method for processing digital topography data that can subsequently be entered in a data base to include slope, slope length, elevation, and aspect. It is expected that this information, and subsequent second and third level interpretive information derived from the original source data, can be used by land resource managers.

The current software programs have been written for an input data tape formatted as per the DMA Planar map data file format. Another tape format from the DMA is available to users whereby the data are referenced to the latitude, longitude coordinate system in terms of 3, 1, or .5 arc sec cell sizes. The former data format is used at the ERL since the majority
### TABLE II.- COMPARISON OF ELEVATION VALUES FROM MAP AND TOPO PROGRAM

<table>
<thead>
<tr>
<th>Point Number</th>
<th>Elevation from 1:62,500 map, ft.</th>
<th>Elevation from TOPO Program, ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7000</td>
<td>7000 - 7100</td>
</tr>
<tr>
<td>2</td>
<td>8171</td>
<td>8000 - 8100</td>
</tr>
<tr>
<td>3</td>
<td>8304</td>
<td>8100 - 8300</td>
</tr>
</tbody>
</table>

### TABLE III.- UTM DIFFERENCES FOR KNOWN POSITIONS

<table>
<thead>
<tr>
<th>TAPE ID</th>
<th>FILE</th>
<th>UTM Δ, meters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sheet Corner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X  Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X  Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X  Y</td>
</tr>
<tr>
<td>RCC-135</td>
<td>3</td>
<td>18  61  0  0  127  9  58  27</td>
</tr>
<tr>
<td>RCC-135</td>
<td>4</td>
<td>0  0  31  86  48  7  42  33</td>
</tr>
<tr>
<td>RCC-136</td>
<td>3</td>
<td>0  0  1  103  22  1  17  1</td>
</tr>
</tbody>
</table>

24
of the Laboratory applications are concerned with the utilization of map data that are based on the UTM reference grid system.
REFERENCES

This appendix defines the procedures and technique involved in processing digital terrain data tapes produced by the DMATC.

This processing necessitates the execution of four separate programs from which is output four data files (elevation, slope, aspect and slope length) which are in a form suitable for entering in the Gridded Data Base. Additional information can be obtained in the DMA TOPO Program Documentation manual on file with the NASA/ERL. The hardware required is a Varian V70 series minicomputer with the following program memory requirements:

Program 1 - 511008
Program 2 - 636008
Program 3 - 471228
Program 4 - 473738

One card reader, a line printer, and two tapes or disk files are required. The individual programs are run in the sequence as defined in this appendix.
PROGRAM 1 - TOPREF
DECK SETUP FOR PROGRAM Program 1 -- TOPO REFORMAT PAGE NO. 1 OF 1

<table>
<thead>
<tr>
<th>(Back of deck)</th>
</tr>
</thead>
</table>

/ENDJOB.

/EXEC, TOPREF.

/ACCESS, CDINOUT, MT, REFORMATTED OUTPUT TAPE.

*/COPYF, CDMAIN, FL. SKIP FILE(S) TO DATA FILE.

/ACCESS, CDMAIN, MT, REELNO. NCIC INPUT TAPE.

/JOB, ---STANDARD JOB CARD.

(Front of deck)

* Data is contained in the second tape file of each group of 3 files for each area. For a four area tape, skip 1, 4, 7, or 10 files to be positioned at the desired data file.

A-3
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD</th>
<th>L.D.</th>
<th>SYMBOLIC</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No card input to this program.</td>
</tr>
</tbody>
</table>

**COMMENTS**

A-4

**ORIGINAL PAGE IS OF POOR QUALITY**
PROGRAM 2 - TOPTWO
DATA CARDS.

/EXEC, TOPMOD.

/ACCESS, CDMAIN, MT, L9xxxx, REFORMATTED INPUT.

/ACCESS, CDMOUT, DD.

/CREATE, CDMOUT^XXXXX, 7200,200/s.

/JOB, --- STANDARD JOB CARD.
<table>
<thead>
<tr>
<th>FIELD 1.D</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-12</td>
<td>D12.2</td>
<td>X0</td>
<td>Easting output origin in meters, minus 1/2 output cell size.</td>
</tr>
<tr>
<td>2</td>
<td>13-24</td>
<td>D12.2</td>
<td>Y0</td>
<td>Northing output origin in meters, minus 1/2 output cell size.</td>
</tr>
<tr>
<td>3</td>
<td>25-36</td>
<td>D12.2</td>
<td>XE</td>
<td>Easting output limit, plus 1/2 output cell size.</td>
</tr>
<tr>
<td>4</td>
<td>37-48</td>
<td>D12.2</td>
<td>YE</td>
<td>Northing output limit, plus 1/2 output cell size.</td>
</tr>
<tr>
<td>5</td>
<td>49-60</td>
<td>D12.2</td>
<td>XORG</td>
<td>Map sheet corner, easting1</td>
</tr>
<tr>
<td>6</td>
<td>61-72</td>
<td>D12.2</td>
<td>YORG</td>
<td>Map sheet corner, northing1</td>
</tr>
</tbody>
</table>

**Field input example**

- Easting output origin: 649950. Input as 649950D2
- Northing output origin: 3985597.81. Input as 398559781D0

*Map sheet corner = SW corner for east file and SE corner for west file of quad map.*
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>I5</td>
<td>ISTART</td>
<td></td>
<td>Record number on input file to start processing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Default = 1.</td>
</tr>
<tr>
<td>2</td>
<td>6-15</td>
<td>F10.0</td>
<td>CELL</td>
<td></td>
<td>Output cell size in meters.</td>
</tr>
<tr>
<td>3</td>
<td>16-25</td>
<td>F10.0</td>
<td>CB</td>
<td></td>
<td>Column bias in meters.</td>
</tr>
<tr>
<td>4</td>
<td>26-35</td>
<td>F10.0</td>
<td>RB</td>
<td></td>
<td>Row bias in meters.</td>
</tr>
<tr>
<td>FIELD</td>
<td>CARD COLUMNS</td>
<td>FORMAT</td>
<td>SYMBOLIC NAME</td>
<td>IDENTIFICATION</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>---------</td>
<td>---------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1-20</td>
<td>D20.10</td>
<td>DELTA</td>
<td>Rotation angle for easting bias (degrees).&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>21-40</td>
<td>D20.10</td>
<td>THETA</td>
<td>Rotation angle for map misalignment (degrees).&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>I1</td>
<td>LQ</td>
<td>=1 for processing left quadrant, otherwise blank.</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>The DELTA angle is determined from:

\[ \tan \Delta = \frac{E_2 - E_1}{(N_2 - N_1)} \]

where the subscript 2 refers to the top sheet coordinates and the subscript 1 refers to the bottom sheet coordinates of the Quad map centerline. For an input data file relative to the Zone CM, the "sign" of the DELTA angle is as follows:

- Negative: East of Zone CM, left half of Quad
- Positive: East of Zone CM, right half of Quad
- Positive: West of Zone CM, left half of Quad
- Negative: West of Zone CM, right half of Quad

<sup>2</sup>THETA is normally zero, but should be verified by checking the X sheet corners of the central meridian of the Quad map.
<table>
<thead>
<tr>
<th>FIELD I.D.</th>
<th>CARD NO.</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.0</td>
<td>XORI</td>
<td>X (.01 inches) of pivot point. *</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.0</td>
<td>YORI</td>
<td>Y (.01 inches) of pivot point.</td>
<td></td>
</tr>
</tbody>
</table>

*1: Pivot point is SW corner for east file and SE corner for west file of Quad map.
1 1-20 D20.10 SYL Scale factor, y-left.

2 21-40 D20.10 SYR Scale factor, y-right.

3 41-60 D20.10 SXB Scale factor, x-bottom.

4 61-80 D20.10 SXT Scale factor, x-top.
<table>
<thead>
<tr>
<th>FIELD I.D.</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.0</td>
<td>XL</td>
<td>X (.01 inches) of SW corner of map.</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.0</td>
<td>XR</td>
<td>X (.01 inches) of SE corner.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.0</td>
<td>YB</td>
<td>Y (.01 inches) of SW corner.</td>
</tr>
<tr>
<td>4</td>
<td>31-40</td>
<td>F10.0</td>
<td>YT</td>
<td>Y (.01 inches) of NW corner.</td>
</tr>
</tbody>
</table>
PROGRAM 3 - TOPSRT
DECK SETUP FOR PROGRAM TOPO - PROGRAM 3

/ENDJOB.

DATA CARD

/EXEC, TOPSRT.

/ACCESS, SRTTAP, MT,,SORTED DATA TAPE OUTPUT.

** /ACCESS, CDMSRT, DD.

/ACCESS, CDMSRT, DD.

* /CREATE, CDMSRT, 7200, NRECS*. SCRATCH FILE.

/JOB,...STANDARD JOB CARD

(Front of deck)

* Number of records required for scratch file is determined by number of records output to file 'CDMOUT' from previous PROGRAM-2.

** File 'CDMOUT' output from previous PROGRAM-2.
## Lead Card Set Up

**Programmer:** J. Forbes  
**Date:** 5/28/78

<table>
<thead>
<tr>
<th>Field</th>
<th>Card No.</th>
<th>Format</th>
<th>Symbolic Name</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>I5</td>
<td>NREC</td>
<td>Number of records on input file 'CMDOUT'.</td>
</tr>
<tr>
<td>2</td>
<td>6-10</td>
<td>I5</td>
<td>IROW</td>
<td>Starting row number.</td>
</tr>
<tr>
<td>3</td>
<td>11-15</td>
<td>I5</td>
<td>IROW</td>
<td>Last row number.</td>
</tr>
<tr>
<td>4</td>
<td>16-20</td>
<td>I5</td>
<td>NTROWS</td>
<td>Total rows (calculated in program 2).</td>
</tr>
<tr>
<td>5</td>
<td>21-25</td>
<td>I5</td>
<td>NCOL</td>
<td>Number of columns.</td>
</tr>
</tbody>
</table>

**Comments:** This input is determined from printed output from previous program-2.
PROGRAM 4 - TOPODB
DECK SETUP FOR PROGRAM TOPO - PROGRAM 4

(Back of deck)

/ENDJOB

DATA CARDS

/EXEC, TOPODB.

/ACCESS, LNDATA, DD.2

/ACCESS, ASDATA, DD.2

/ACCESS, SLDATA, DD.2

/ACCESS, ELDATA, DD.

* /CREATE, LNDATA, 1080, NRECS/S. SLOPE LENGTH DATA.

* /CREATE, ASDATA, 1080, NRECS/S. ASPECT DATA.

* /CREATE, SLDATA, 1080, NRECS/S. SLOPE DATA.

* /CREATE, ELDATA, 1080, NRECS/S. ELEVATION DATA.

/ACCESS, SRTTAP, MT, L9XXXX, OUTPUT FROM PGM-3.

/JOB, --- STANDARD JOB CARD.

(Front of deck)

* Number of records output is determined by number of rows processed (see Lead Cards).

1 Omit this file if I$OPT = 2 (lead card #1)

2 Omit these files if I$OPT = 1

A-17
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>I5</td>
<td>ISR</td>
<td>ISR</td>
<td>Record number (row) on input file to start processing. Default = 1.</td>
</tr>
<tr>
<td>2</td>
<td>6-10</td>
<td>I5</td>
<td>ICOL</td>
<td>ICOL</td>
<td>Starting column number to process.</td>
</tr>
<tr>
<td>3</td>
<td>11-15</td>
<td>I5</td>
<td>LCOL</td>
<td>LCOL</td>
<td>Stop column number.</td>
</tr>
<tr>
<td>4</td>
<td>16-25</td>
<td>F10.2</td>
<td>CELL</td>
<td>CELL</td>
<td>Cell size in meters.</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>I1</td>
<td>IOPT</td>
<td>IOPT</td>
<td>Processing option:</td>
</tr>
</tbody>
</table>

- 0 = Process all.
- 1 = Process elevation data only.
- 2 = Process slope, aspect and slope length only.

COMMENTS
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD NO.</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>I5 IROW</td>
<td>First row number for output file (input to database).</td>
</tr>
<tr>
<td>2</td>
<td>6-10</td>
<td>I5 LROW</td>
<td>Ending row number for output.</td>
</tr>
<tr>
<td>3</td>
<td>11-15</td>
<td>I5 ICBIAS</td>
<td>Column bias for shifting output.</td>
</tr>
<tr>
<td>FIELD I.D.</td>
<td>CARD COLUMNS</td>
<td>FORMAT</td>
<td>SYMBOIC NAME</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>1-8</td>
<td>F8.0</td>
<td>STELV</td>
</tr>
<tr>
<td>2</td>
<td>9-16</td>
<td>F8.0</td>
<td>ENDELV</td>
</tr>
<tr>
<td>3</td>
<td>17-24</td>
<td>F8.0</td>
<td>ENCR</td>
</tr>
</tbody>
</table>

COMMENTS
Omit this card if IOPT (card 1) = 2
### CARD

**NO.** 4  
**JOB** TOPO - PROGRAM 4  
**NAME** TOPODB  

---

**LEAD CARD SET UP**  
**PROGRAMMER** J. Forbes  
**DATE** 5/28/78  

<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD ID.</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>T5</td>
<td>NSL</td>
<td><strong>Identification</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Number of slope levels to read (following).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MAX = 20.</td>
<td></td>
</tr>
</tbody>
</table>

---

**COMMENTS**  
Omit this card if OPT = 1
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD</th>
<th>SYMBOlic NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-8</td>
<td>XSSL(1)</td>
<td>Starting slope level (1).</td>
</tr>
<tr>
<td>2</td>
<td>9-16</td>
<td>XSSL(2)</td>
<td>Starting slope level (2).</td>
</tr>
<tr>
<td>3</td>
<td>17-24</td>
<td>XSSL(3)</td>
<td>Starting slope level (3).</td>
</tr>
<tr>
<td>4</td>
<td>25-32</td>
<td>XSSL(4)</td>
<td>Starting slope level (4).</td>
</tr>
<tr>
<td>5</td>
<td>33-40</td>
<td>XSSL(5)</td>
<td>Starting slope level (5).</td>
</tr>
<tr>
<td>6</td>
<td>41-48</td>
<td>XSSL(6)</td>
<td>Starting slope level (6).</td>
</tr>
<tr>
<td>7</td>
<td>49-56</td>
<td>XSSL(7)</td>
<td>Starting slope level (7).</td>
</tr>
<tr>
<td>8</td>
<td>57-64</td>
<td>XSSL(8)</td>
<td>Starting slope level (8).</td>
</tr>
<tr>
<td>9</td>
<td>65-72</td>
<td>XSSL(9)</td>
<td>Starting slope level (9).</td>
</tr>
<tr>
<td>10</td>
<td>73-80</td>
<td>XSSL(10)</td>
<td>Starting slope level (10).</td>
</tr>
</tbody>
</table>

Input 'NSL' values (card number 4).

Comments: Input 2 of these cards if more than 10 slope levels.
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CARD NO.</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-2</td>
<td>I2</td>
<td>IASP(1)</td>
<td>Aspect number code for undetermined.</td>
</tr>
<tr>
<td>2</td>
<td>3-4</td>
<td>I2</td>
<td>IASP(2)</td>
<td>Aspect number code for NORTH.</td>
</tr>
<tr>
<td>3</td>
<td>5-6</td>
<td>I2</td>
<td>IASP(3)</td>
<td>Aspect number code for NE.</td>
</tr>
<tr>
<td>4</td>
<td>7-8</td>
<td>I2</td>
<td>IASP(4)</td>
<td>Aspect number code for E.</td>
</tr>
<tr>
<td>5</td>
<td>9-10</td>
<td>I2</td>
<td>IASP(5)</td>
<td>Aspect number code for SE.</td>
</tr>
<tr>
<td>6</td>
<td>11-12</td>
<td>I2</td>
<td>IASP(6)</td>
<td>Aspect number code for S.</td>
</tr>
<tr>
<td>7</td>
<td>13-14</td>
<td>I2</td>
<td>IASP(7)</td>
<td>Aspect number code for SW.</td>
</tr>
<tr>
<td>8</td>
<td>15-16</td>
<td>I2</td>
<td>IASP(8)</td>
<td>Aspect number code for W.</td>
</tr>
<tr>
<td>9</td>
<td>17-18</td>
<td>I2</td>
<td>IASP(9)</td>
<td>Aspect number code for NW.</td>
</tr>
</tbody>
</table>

COMMENTS: Omit this card if I0PT = 1
<table>
<thead>
<tr>
<th>FIELD I.D.</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1X</td>
<td></td>
<td></td>
<td>Blank</td>
</tr>
<tr>
<td>1 2</td>
<td>II</td>
<td>IP∅</td>
<td></td>
<td>1 = yes, 0 = no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Print elevation, slope and aspect printer maps.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1X</td>
<td></td>
<td></td>
<td>Blank</td>
</tr>
<tr>
<td>2 4</td>
<td>II</td>
<td>ISL∅P</td>
<td></td>
<td>1 = yes, 0 = no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Print slope lengths for each cell.</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B

PROGRAM FLOW CHARTS
Program 1 - TOPREF

START

A

NCIC Multi-file Tape

Read 15850 word records. Write 2005-word records arranged 1 column per record, with zero fill at end.

Reformatted Tape

Summary data for each record written.

AT END

STOP
Program 2 - TOPTWO

START

Read card input control parameters for area to process.

A

Reformatted tape.

Read input tape. Search for applicable rows and columns, apply rotation and scale factors.

Write X-coord, Y-coord and elevation value for each point to disc file, in 7200 word recs.

Disc file 'CDMOUT'

A

AT END

STOP
PROGRAM 3 - TOPSRT

START

Read card control parameters: number of records, first row, last row, total rows from all files, number of columns this file.

A

Disc file 'CDMOUT'

Read disc file from Program 2. Pull off data for Y-coordinates in reverse order, starting with last row. Write 7200 word records to scratch disc file.

A

AT END

B

(continued)

B-4
Program 3 (continued)

- Read scratch disc file. Average data to obtain required output cell size.
- Write record containing row number and data values for each column.

B

AT END

STOP
Read control parameters and level tables.

Read row data from sorted tape, 3 rows at a time. Compute slope, aspect and slope length for each cell from 8 surrounding cells for all selected columns. Write to disc files.

Elevation data.
Slope data.
Aspect data.
Slope length data.

AT END
Program 4 (continued)

B

PRINT?

NO

YES

Read disc files
print out data.

PRINT
dISTRIBUTION

STOP

PRINT
MAPS
APPENDIX C

PROGRAM LISTINGS
C-2  
ORIGINAL PAGE IS  
OF POOR QUALITY
60 165 CALL V&WR(OPN,2005,IA,I)
61 IF(I .EQ. -2) GO TO 165
62 K = K + (IN(K-2)/2)
63 IF(K .GT. NWD8) GO TO 90
64 GO TO 130
65 C
66 900 CONTINUE
67 WRITE(5,1006) MIN,MAX
68 WRITE(5,1005)
69 CALL V&R(OPN)
70 CALL V&R(IFN)
71 CALL V&R(OPN)
72 STOP
73 END
DATA CON/O.U17453292DO/
DATA TFN,OFN/
CALL PAGE 4 01/04/78 47133000 VORTEX FTN IV(G) 8148 A1 0924 HOURS

60 WRITE(5,1000) XO,YO,XE,YE,XORG,YOR
61 WRITE(5,1100) NROW,NCOL,ISTART,CELL,CR,RR
62 WRITE(5,1102) DELTA,THETA,LG,XORG,YOR
63 WRITE(5,1103) SYL,SYN,SX,SX,SY,SR,SY,SR
64 C
65 LROW = NPDW
66 KROW = 0
67 XCELL = CELLL
68 THETA = THETA*CON
69 DELTA = DELTA*CON
70 DBL1 = CB
71 XO = XO+DBL1
72 XE = XE+DBL1
73 DBL1 = RB
74 YO = YO+DBL1
75 YE = YE+DBL1
76 DBL1 = XR
77 DBL2 = XG
78 YM = (SYM-SYL)/(DBL1-DBL2)
79 BY = SYL+YM*DBL2
80 DBL1 = YT
81 DBL2 = YB
82 XM = (SX+SXB)/(DBL1-DBL2)
83 BX = SXM-XM*DBL2
84 ICN = 0
85 IVL = 0
86 NRO = 0
87 IXC = 1
88 A = 0.0
89 YC1 = 0.000
90 IYP = 0
91 IYL = 1
92 NLIN = 65
93 DBL1 = DSIN(Delta)
94 DBL2 = DCOS(Delta)
95 200 CONTINUE
96 CALL VORD(IFM,2005,IA,IST)
97 IF(IST.GT.0) GO TO 205
98 IF(IST.EQ.-1) GO TO 210
99 205 CONTINUE
100 IF(LX .LT. 1) GO TO 200
101 ICN = ICN + 1
102 IF(IXC .LT. ISTART) GO TO 200
103 IF(IXC .GT. ISTART) GO TO 220
104 XG = LX
105 YG = LY
106 WRITE(5,1005) LX,LY
107 CALL PAGE 4
108 220 CONTINUE
109 XP = LX
110 YP = YC
111 XOR = XOR
112 YOR = YOR
113 XP = XP+XOR
114 YP = YP+YOR
115 IF (LO) 230,225,230
116 230 IF(IFP) (XP*DBL2) = (YP*(DBL1+DBL1)+DBL2) *(YP*DBL2)
117 XPP = (XP*DBL2)-(YP*DBL2)

C-5
GO TO 235

230 YPP = (X*DBL1) - (YPP*DBL1+DBL1*YPP) + (YPP*DBL2)

235 CONTINUE

SX = X*YPP+BX
SY = YM*XPP+BY
X1 = XPP*SYM

IF (X1.LT.XO) GO TO 200
IF (X1.GT.XE) GO TO 200

Y(I) = YPP*SYM

YA(I) = IA(I)

N1 = 7
DO 240 I = 2,N

Y(I) = Y(I-1)+SY
YA(I) = YA(I)

240 CONTINUE

IVL = IVL+1

250 CONTINUE

IX = (X1-XO)/CELL + 1

IF (IX.LE.0) GO TO 260
IF (IX.GT.NCOL) GO TO 260
IF (NLIN.LT.55) GO TO 261

IROW = IX

WRITE(5,1007) IR,IVL,ZX,JXX,Y11,Y12,YJ1,YJ2

IF(IVL.EQ.1) ICOL = IX

260 CONTINUE

118 PAGE 5 01/04/78 471W3000 VÒRTXII PTN IV(G) B168A1 0924 HOURS

C

120 YPP = (X*DBL1) - (YPP*DBL1+DBL1*YPP) + (YPP*DBL2)

121 XPP = (X*DBL2)+(YPP*DBL1)

122 SX = X*YPP+BX

123 SY = YM*XPP+BY

124 X1 = XPP*SYM

125 IF (X1.LT.XO) GO TO 200

126 IF (X1.GT.XE) GO TO 200

127 Y(I) = YPP*SYM

128 YA(I) = IA(I)

129 N1 = 7

130 DO 240 I = 2,N

131 Y(I) = Y(I-1)+SY

132 YA(I) = YA(I)

133 N1 = N1 + 1

134 240 CONTINUE

135 IVL = IVL+1

136 J = 0

137 DO 252 I = 1,N

138 IF(Y(I).LT.Y0) GO TO 282

139 IF(Y(I).GT.YE) GO TO 285

140 Y(J) = Y(I)

141 YJ(J) = YJ(I)

142 JA(J) = JA(I)

143 252 CONTINUE

144 255 CONTINUE

145 IX = (X1-XO)/CELL + 1

146 IF (IX.LE.0) GO TO 260

147 IF (IX.GT.NCOL) GO TO 260

148 IF (NLIN.LT.55) GO TO 261

149 CALL PAGE

150 WRITE(S,1007) IR,IVL,ZX,JXX,Y11,Y12,YJ1,YJ2

151 ICOL = IX

152 NLIN = 0

153 261 CONTINUE

154 XX = X1

155 Y11 = Y(1)

156 Y12 = Y(1)

157 YJ1 = Y(J)

158 YJ2 = Y(J)

159 NNLIN = NLIN + 1

160 WRITE(S,1006) IR,IVL,IX,JXX,Y11,Y12,YJ1,YJ2

161 IF (IVL.EQ.1) ICOL = IX

162 DO 270 J = 1,Y

163 IY = (Y(I)-Y0)/XCELL + 1

164 IF (IV.LT.0) GO TO 270

165 IF (IV.GT.YR) GO TO 270

166 IF (IVL.EQ.1) ICOL = IY

167 IF (IVL.EQ.1) IRW = IY

168 IF (IVL.EQ.1) IRW = IY

169 270 CONTINUE

170 A = A + ABS(YA(I)) + 1

171 ITL = 2

172 ITP = IX

173 IYP = IY

174 ICI = ICI + 1.00

175 GO TO 270

ORIGINAI PAGE IS OF POOR QUALITY
176  265  YCS = YC1
177  265  IF (IYP.GT.KROW) KROW=IYP
178  265  IB(IXC+2) = A/YCS
179  265  IB(IXC+1) = IYP
180  265  IB(IXC) = IXP
181  265  A = 0.0
182  265  YC1 = 0.000
183  265  IXC = IXC + 3
184  265  IF (IXC.LE.7200) GO TO 252
185  265  CALL VSWR(OFN,7200,IR,IST)
186  265  IXC = 1
187  265  IF (IST.EQ.-4) GO TO 280
188  265  NRO = NRO + 1
189  270  GO TO 262
190  270  CONTINUE
191  270  IYL = 2
192  270  CONTINUE
193  270  IF (IYP.GE.LROW) GO TO 200
194  270  NXTP = IYP
195  275  DO 275 K = NXTP,LROW
196  275  IB(IXC) = IXP
197  275  IB(IXC+1) = K
198  275  IB(IXC+2) = 0
199  275  IXC = IXC+3
200  275  IF (IXC.LE.7200) GO TO 275
201  275  CALL VSWR(OFN,7200,IR,IST)
202  275  IXC = 1
203  275  IF (IST.EQ.-4) GO TO 280
204  275  NRO = NRO+1
205  275  CONTINUE
206  280  GO TO 200
207  280  CONTINUE
208  290  IF (IX.GT.NCOL) IX = IX-1
209  290  LCOL = IX
210  290  IF (IXC.EQ.1) GO TO 290
211  290  DO 285 I = IXC,7200
212  285  IB(1) = 0
213  285  CALL VSWR(OFN,7200,IR,IST)
214  285  NRO = NRO + 1
215  290  CONTINUE
216  290  CALL VSWP(OFN)
217  290  WRITE(5,1003) NRO,IROW,KROW,LCOL,LCOL
218  290  STOP
219  290  END
C-8
C-9
118 \( IC = IC + 1 \)
119 IF \( IC > GT. 1 \) GO TO 410
120 403 CONTINUE
121 \( IY = ODAT(I+1) \)
122 IF \( IY = EQ. 0 \) GO TO 500
123 405 CONTINUE
124 \( IX = ODAT(I) \)
125 \( \text{SUM} = 0. \)
126 \( XN = 0. \)
127 410 CONTINUE
128 IF \( ODAT(I+1) = EQ. 0 \) GO TO 500
129 IF \( TX = NE. 0 \) GO TO 420
130 IF \( TX = NE. ODAT(T) \) GO TO 420
131 \( XN = XN + 1.0 \)
132 \( \text{SUM} = \text{SUM} + ODAT(I+2) \)
133 GO TO 500
134 420 CONTINUE
135 \( AR(IX+1) = \text{SUM/}XN \)
136 GO TO 405
137 450 CONTINUE
138 \( AR(IX+1) = \text{SUM/}XN \)
139 \( AR(1) = IY \)
140 \( M0 = \text{MOD(IY,} 10 \) \)
141 IF \( M0 = EQ. 0 \) \text{WRITE}(5,1002) IY
142 CALL VSWR(IFAR,2160,AR,IST)
143 \( NRT = NRT + 1 \)
144 DO 480 J = 1,NCOL
145 \( AR(J) = 0.0 \)
146 480 CONTINUE
147 GO TO 403
148 500 CONTINUE
149 \( IC = 1 \)
150 GO TO 400
151 600 CONTINUE
152 \( AR(IX+1) = \text{SUM/}XN \)
153 \( AR(1) = IY \)
154 \text{WRITE}(5,1002) IY
155 CALL VSWR(IFAR,2160,AR,IST)
156 \( NRT = NRT + 1 \)
157 \text{WRITE}(5,1003) NRT
158 CALL VSEF(IFAR)
159 CALL VSEF(IFAR)
160 800 CONTINUE
161 \text{STOP}
162 \text{END}
<table>
<thead>
<tr>
<th>Page 10</th>
<th>01/04/78 47183000 VORTXII FTW IV(G) D148A1 0927 HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NAME TOPNDR</td>
</tr>
<tr>
<td>2</td>
<td>TITLE D148A1</td>
</tr>
<tr>
<td>3</td>
<td>INTEGR EFN, SFN, AFN</td>
</tr>
<tr>
<td>4</td>
<td>DIMENSION AR(1080), IXELV(1080), IXSLP(1080), IXASP(1080)</td>
</tr>
<tr>
<td>5</td>
<td>DIMENSION ELEC(1000,3), AP(8), DIFF(8), DIST(8), ICH(20), IASP(9)</td>
</tr>
<tr>
<td>6</td>
<td>DIMENSION P (2), ELE (2), SLO (2), ASP (2), IFN (3), EFN (3), SFN (3), AFN (3)</td>
</tr>
<tr>
<td>7</td>
<td>DIMENSION XSL(200), XSF(20), XSEL(254), XEEL(254)</td>
</tr>
<tr>
<td>8</td>
<td>DIMENSION T(1008), LFN(3), SLEN(2)</td>
</tr>
<tr>
<td>9</td>
<td>DIMENSION FLF(254)</td>
</tr>
<tr>
<td>10</td>
<td>DATA ELF/2540.0/</td>
</tr>
<tr>
<td>11</td>
<td>DATA LFN/'IN', 'DA', 'TA'/</td>
</tr>
<tr>
<td>12</td>
<td>DATA SLEN/'S.L.', 'NGTH'/</td>
</tr>
<tr>
<td>13</td>
<td>DATA ELE, SLO, ASP/'ELVF', 'SLOP', 'ASPE', 'CT'/</td>
</tr>
<tr>
<td>14</td>
<td>DATA IFN, EFN, SFN, AFN/'SF', 'TT', 'AP', 'EL', 'DA', 'TA', 'SL', 'DA', 'TA'/</td>
</tr>
<tr>
<td>15</td>
<td>X, 'AS', 'DA', 'TA'/</td>
</tr>
<tr>
<td>16</td>
<td>510 FORMAT('1H ,2A4,' DATA COLUMNS', '15,' TO ',15)</td>
</tr>
<tr>
<td>17</td>
<td>511 FORMAT('DIVIDED BY 10')</td>
</tr>
<tr>
<td>18</td>
<td>530 FORMAT('1X4,1X120A1)</td>
</tr>
<tr>
<td>19</td>
<td>531 FORMAT('1X4,1X120I1)</td>
</tr>
<tr>
<td>20</td>
<td>532 FORMAT('I4,130T1')</td>
</tr>
<tr>
<td>21</td>
<td>501 FORMAT('315,F10.2,4X,11')</td>
</tr>
<tr>
<td>22</td>
<td>1001 FORMAT('315')</td>
</tr>
<tr>
<td>23</td>
<td>1003 FORMAT('10F8.0')</td>
</tr>
<tr>
<td>24</td>
<td>1004 FORMAT('DIVIDED BY 10)</td>
</tr>
<tr>
<td>25</td>
<td>1100 FORMAT('I INPUT COLUMNS TO PROCESS = ',2I7,/,</td>
</tr>
<tr>
<td>26</td>
<td>' INPUT STARTING ROW = ',15,/,</td>
</tr>
<tr>
<td>27</td>
<td>' CELL SIZE = ',F8.2,/,</td>
</tr>
<tr>
<td>28</td>
<td>' PROCESSING OPTION = ',I17,7,</td>
</tr>
<tr>
<td>29</td>
<td>' NUMBER OF ROWS OUTPUT = ',15, ' FROM ',I15,' TO ',I15,/,</td>
</tr>
<tr>
<td>30</td>
<td>' COLUMNS OUTPUT NUMBERED FROM ',I15,' TO ',I15,/)</td>
</tr>
<tr>
<td>31</td>
<td>1199 FORMAT('EPSL.EMO.02/ LEVELS COMPUTED IN INCREMENTS OF ',F6.1,</td>
</tr>
<tr>
<td>32</td>
<td>' FROM ',F8.1, ' TO ',F8.1/,</td>
</tr>
<tr>
<td>33</td>
<td>' LEVEL ,16X,'ST. ELV. ,15X,'END ELV. ,/</td>
</tr>
<tr>
<td>34</td>
<td>1200 FORMAT('NUMBER OF QUANTUM LEVELS FOR SLOPE=',I5,/,</td>
</tr>
<tr>
<td>35</td>
<td>' 8X,'LEVEL', '17X,'ST,SL', '15X,'END SL. ,/</td>
</tr>
<tr>
<td>36</td>
<td>1201 FORMAT('5X,13,5X,A1,2X,2(12X,F10.1))</td>
</tr>
<tr>
<td>37</td>
<td>1202 FORMAT('6X,2X,2(12X,F10.1))</td>
</tr>
<tr>
<td>38</td>
<td>1400 FORMAT('X, ASPECT OUTPUT (CLOCKWISE FROM NORTH) ',9I4)</td>
</tr>
<tr>
<td>39</td>
<td>1500 FORMAT('PRINT OPT. =',I2, ' SLOPE LENGTH PRINT OPT. =',I2,/,</td>
</tr>
<tr>
<td>40</td>
<td>X  'O - NO, 1 = YES')</td>
</tr>
<tr>
<td>41</td>
<td>2001 FORMAT('** ERROR ** SLOPE = ',F12.1, ' IX = ',I6, ' IY = ',I6)</td>
</tr>
<tr>
<td>42</td>
<td>2002 FORMAT('** ERROR ** ELEV. = ',F12.1, ' IX = ',I6, ' IY = ',I6)</td>
</tr>
<tr>
<td>43</td>
<td>2005 FORMAT('I ELEVATION DISTRIBUTION ***',/</td>
</tr>
<tr>
<td>44</td>
<td>' LEVEL TOTAL CELLS')</td>
</tr>
<tr>
<td>45</td>
<td>2006 FORMAT('10X,13,F15.0')</td>
</tr>
<tr>
<td>46</td>
<td>C</td>
</tr>
<tr>
<td>47</td>
<td>C</td>
</tr>
<tr>
<td>48</td>
<td>CARD INPUT</td>
</tr>
<tr>
<td>49</td>
<td>C</td>
</tr>
<tr>
<td>50</td>
<td>C CARD 1 -5 (I5) ROW NUMBER ON INPUT FILE TO START</td>
</tr>
<tr>
<td>51</td>
<td>Cols 6-10 - (I5) Cols 11-15 STOP COLUMNS ON INPUT FILE.</td>
</tr>
<tr>
<td>52</td>
<td>Cols 11-15 STOP COLUMNS ON INPUT FILE.</td>
</tr>
<tr>
<td>53</td>
<td>Cols 16-25 (F10.2)</td>
</tr>
<tr>
<td>54</td>
<td>Cols 30 (I1)</td>
</tr>
<tr>
<td>55</td>
<td>0 = PROCESS ALL</td>
</tr>
<tr>
<td>56</td>
<td>1 = ELEVATION DATA ONLY</td>
</tr>
</tbody>
</table>

**ORIGINAL PAGE IS OF POOR QUALITY**
CARD 2

COLS 1-5 (I5) STARTING ROW NUMBER FOR OUTPUT.

COLS 6-10 (I5) ENDING ROW NUMBER FOR OUTPUT.

COLS 11-15 (I5) COLUMN BIAS FOR SHIFTING OUTPUT.

CARD 3 - (COMPUTES A MAX OF 254 LEVELS)

COLS 1-8 (F8.0) STARTING ELEVATION LEVEL.

COLS 9-16 (F8.0) ENDING ELEVATION LEVEL.

COLS 17-24 (F8.0) ELEV. LEVEL INCREMENT.

CARD 4

COLS 1-5 (I5) NUMBER OF SLOPE LEVELS, INPUT TO FOLLOW. MAX 20

CARD 5 - (6)

COLS 1-8 (F8.0) START SLOPE LEVEL (1).

COLS 9-16 (F8.0) START SLOPE LEVEL (2).

COLS 17-24 (F8.0) START SLOPE LEVEL (3).

COLS 25-32 (F8.0) START SLOPE LEVEL (4).

COLS 33-40 (F8.0) START SLOPE LEVEL (5).

COLS 41-48 (F8.0) START SLOPE LEVEL (6).

COLS 49-56 (F8.0) START SLOPE LEVEL (7).

COLS 57-64 (F8.0) START SLOPE LEVEL (8).

COLS 65-72 (F8.0) START SLOPE LEVEL (9).

COLS 73-80 (F8.0) START SLOPE LEVEL (10).

INPUT 1 OR 2 CARDS DEPENDING ON CARD 4. (10 PER CARD)

CARD 7 ASPECT OUTPUT PARAMETERS

COLS 1-2 (12) NUMBER CODE FOR UNDETERMINED.

COLS 3-4 (12) NUMBER CODE FOR NORTH.

COLS 5-6 (12) NUMBER CODE FOR NE.

COLS 7-8 (12) NUMBER CODE FOR E.

COLS 9-10 (12) NUMBER CODE FOR SE.

COLS 11-12 (12) NUMBER CODE FOR S.

COLS 13-14 (12) NUMBER CODE FOR SW.

COLS 15-16 (12) NUMBER CODE FOR W.

COLS 17-18 (12) NUMBER CODE FOR NW.

CARD 8 - PRINT OPTIONS

0 = NO 1 = YES

CARD 2 PRINT ELEVATION, SLOPE AND ASPECT MAPS

CARD 4 PRINT SLOPE LENGTH CALCULATIONS.

CALL CSINIT

CALL PAGE

READ (4,1001) ISR,ICOL,LCOL,CELL,IOPT

READ (4,1002) IRW,LRW,ICBIAS

IF (IOPT.EQ.2) GO TO 5

READ (4,1003) ISLY,INDLY,ENCR

IF (IOPT.EQ.1) GO TO 10

READ (4,1002) NSL

READ (4,1003) ISXL,INDX,NSL

READ (4,1004) IAEP

C-12
READ(4,1004) TO,ISLOP
IF (TOPT.EQ.2) GO TO 38
ENDVL = ENDFLV+ENCR-1.
NEL = ((ENDFLV-STELV)/ENCRL)+2.
IF (NEL.LE.254) GO TO 30
ENCRL = ENCR+10.
GO TO 20
XSEL(I) = 0.
XSFJ(2) = STELV
XSEL(2) = XSEL(I) + FNCR
DO 35 I = 3, NEL
XSEL(I) = XSEL(I-1)+FNCR
XSEL(I) = XSEL(I-1)+FCRP
CONTINUE
XSEL(NFL) = 99999.
IF (TOPT.EQ.1) GO TO 42
NL = NSL-1
DO 40 J = 1, NL
XSEL(I) = XSSL(I+1)
CONTINUE
XSEL(NL+1) = 99999.
CONTINUE
NROW = IROW+IROW+1
NCOI = ICOL+ICOL+1
IF (ISR.EQ.0) ISR = 1
NR = NROW+ISR-1
IC = ICOL + ICBIAS
LC = ICL + ICBIAS
WRITE(5,1102) ICOL,LCOL,ISR,CELL,TOPT,NROW,IROW,LCROW,NCOL,IC,LCL
IF (TOPT.EQ.2) GO TO 150
WRITE(5,1199) FCPR,STELV,XSEL(NEL)
IF (NEL.LE.26) GO TO 145
DO 140 I = 1, NEL
WRITE(5,1202) I,XSEL(I),XSEL(I)
CONTINUE
GO TO 150
DO 146 J = 1, NEL
IL = LSL(I+192,8)
WRITE(5,1201) I,IL,XSEL(I),XSEL(I)
CONTINUE
GO TO 170
IF (TOPT,EQ.1) GO TO 1708
WRITE(5,1200) NSL
NL = NSL
DO 170 I = 1, NL
IL = LSL(I+192,8)
WRITE(5,1201) I,IL,XSEL(I),XSEL(I)
CONTINUE
WRITE(5,1400) IASP
WRITE(5,1500) IPD,ISLOP

C-13
176   N3 = 0
177   NCL = NCOL + 1
178   DO 171 I = 1,1000
179   IXFLV(I) = 0
180   IXSLP(I) = 0
181   IXASP(I) = 0
182   IXLEN(I) = 0
183   CONTINUE
184   C
185   C   *** COMPUTE DIST BASED ON CELL SIZE
186   DO 50 I = 1,8
187   DIST(I) = CELL
188   IF(MOD(I,2).EQ.0) DIST(I) = 1.414214*CELL
189   CONTINUE
190   IXFLV(2) = IC
191   IXSLP(2) = IC
192   IXASP(2) = IC
193   IXLEN(2) = IC
194   IXFLV(3) = LC
195   IXSLP(3) = LC
196   IXASP(3) = LC
197   IXLEN(3) = LC
198   C
199   C   *** READ INPUT FILE INTO ROTATING BUFFER
200   C   *** REPEAT FIRST AND LAST RECORDS
201   C
202   100 CONTINUE
203   IF(M .EQ. 1) GO TO 110
204   KTR = KTR+1
205   IF(KTR.GT.4R) GO TO 105
206   CALL VSRD(IFN,2160,AR,IET)
207   IF(KTR.LT.ISR) GO TO 100
208   IF(IET .GT. 0) GO TO 110
209   IST = IST
210   GO TO(110,110,105,105,110,400),IST
211   105 CONTINUE
212   ISTP = 1
213   LD = 3
214   110 CONTINUE
215   IY = AR(1) + 1
216   M = M + 1
217   N3 = N3 + 1
218   IF(N3 .GT. 3) N3 = 1
219   N2 = N3 - 1
220   IF(N2 .EQ. 0) N2 = 3
221   N1 = N2 - 1
222   IF(N1 .EQ. 0) N1 = 3
223   IF(IET .EQ. 1) GO TO 125
224   DO 120 I = 1,LCOL
225   ELEC(I,N3) = AR(I+1)
226   120 CONTINUE
227   GO TO 145
228   125 CONTINUE
229   DO 130 I = 1,LCOL
230   ELEC(I,N3) = ELEC(I,N2)
231   130 CONTINUE
232   145 CONTINUE
233   IF(M .LT. 3) GO TO 100

ORIGINAL PAGE IS OF POOR QUALITY.
**C-15**
IF (MR0W.GT.LROW) GO TO 400
IXFLY(1) = MR0W
IXSLP(1) = MR0W
IXASP(1) = MR0W
IXLEN(1) = MR0W
TF (I0PT.EQ.2) GO TO 320
CALL VSNR(FMN,1080,IXLYV,IST)
TF(IST.EQ.-4) GO TO 350
IF (I0PT.EQ.1) GO TO 330
CALL VSNR(SMN,1080,IXSLP,IST)
CALL VSNR(AMN,1080,IXASP,IST)
CALL VSNR(LMN,1080,IXLRN,IST)
M = 2
LO = 2
IF(IST.EQ.0) GO TO 100
GO TO 400
CONTINUE
IF (I0PT.EQ.2) GO TO 360
CALL VSNR(FMN,1,1)
IF (I0PT.EQ.1) GO TO 400
CALL VSNR(SMN,1,1)
CALL VSNR(AMN,1,1)
CALL VSNR(LMN,1,1)
CONTINUE
IF (I0PT.EQ.2) GO TO 405
CALL VSNRF(FMN)
IF (I0PT.EQ.1) GO TO 410
CALL VSNRF(SMN)
CALL VSNRF(AMN)
CALL VSNRF(LMN)
CONTINUE
IF (I0PT.EQ.0) GO TO 800
IF (I0PT.EQ.2) GO TO 390
CONTINUE
IF (WEL.EQ.26) GO TO 490
NRX = (NCL0L-29)/30
DO 480 I = 1,NRX
CALL VSNFC(FMN,0,1)
CALL PAGE
TS = (T-1)*260 + ICOL
TE = TS+29
IF (TE.GT.LCOL) TE=LCOL
PARM(1) = ELE(1)
PARM(1) = ELE(1)
PARM(2) = ELE(2)
ISA = IS+ICRIAS
IEA = IE+ICRIAS
WRITE(5,510) PARM(1),PARM(2),ISA,IEA
IS = IS-ICOL+4
IE = IE-ICOL+4
CALL VSNRF(FMN,1080,IXLYV,IST)
IF (IST.EQ.-3.OR. IAT.EQ.-4) GO TO 400
IY = IXLYV(1)
WRITE(5,540) IY,(IXLYV(I),KME,IL)
GO TO 420
350  400  CONTINUE
351    NRX = (NCOL+119)/120
352    GO TO 590
353   490  NRX = (NCOL+119)/120
354    DO 500 I = 1,NRX
355    CALL VSF C(FPN,0,1)
356    CALL PAGE$  
357    IS = (I-1)*120 + ICOL
358    IE = IS + 119
359    IF(I.EQ.IST) IF = LCOL
360    PARM(1) = FLG(1)
361    PARM(2) = FLG(2)
362    ISA = IS+ICIAS
363    IEA = IE+ICBIAS
364    WRITE(5,510) PARM(1), PARM(2), ISA, IEA
365    IF(I.EQ.119) IE = LCOL + 4
366    IE = IF=ICOL + 4
367    CALL VSRD(FPN,1080,IXELV,IST)
368    IF(IST.EQ.-3 .OR. IST.EQ.-4) GO TO 500
369    IF = IXELV(1)
370    DO 525 K = TS,TE
371    WRITE(5,530) IXSLP(K), IXSLP(K)+192,8
372    GO TO 520
373  500  CONTINUE
374  590  CONTINUE
375  560  CONTINUE
376  570  CONTINUE
377  580  CONTINUE
378  590  CONTINUE
379  600  CONTINUE
380  610  CONTINUE
381  620  CONTINUE
382  630  CONTINUE
383  640  CONTINUE
384  650  CONTINUE
385  660  CONTINUE
386  670  CONTINUE
387  680  CONTINUE
388  690  CONTINUE
389  700  CONTINUE
390  710  CONTINUE
391  720  CONTINUE
392  730  CONTINUE
393  740  CONTINUE
394  750  CONTINUE
395  760  CONTINUE
396  770  CONTINUE
397  780  CONTINUE
398  790  CONTINUE
399  800  CONTINUE
400  810  CONTINUE
401  820  CONTINUE
402  830  CONTINUE
403  840  CONTINUE
404  850  CONTINUE
405  860  CONTINUE
406  870  CONTINUE
407  880  CONTINUE

C-17
CALL PAGES

IS = (I-1)*120 + ICOL
IE = IS + 119
IF (IE <= LCOL) IE = LCOL
PARM(1) = ASP(1)
PARM(2) = ASP(2)
ISA = IS+ICIAS
IEA = IE+ICIAS
WRITE(5,510) PARM(1), PARM(2), ISA, IEA
IS = IS - ICOL + 4
IE = IE - ICOL + 4
720 CALL VSRD(AFN,1080,IXASP,IST)
IF (IST.EQ.0 .OR. IST.EQ.-4) GO TO 700
TY = IXASP(1)
WRITE(5,531) TY,(IXASP(K),K=18,IE)
GO TO 720
700 CONTINUE
800 CONTINUE
IF (ISLNP.F3.0) GO TO 999
*** PRINT SLOPE LENGTH
30 COLS PER PAGE NRX = (NCOL+29)/30
CALL VSFC(I,FN,0,1)
CALL PAGES
IS = (I-1)*30 + ICOL
IE = IS+29
IF (IE <= LCOL) IE = LCOL
PARM(1) = SLEN(1)
PARM(2) = SLEN(2)
ISA = IS+ICIAS
IEA = IE+ICIAS
WRITE(5,510) PARM(1), PARM(2), ISA, IEA
WRITE(5,511)
IS = IS-ICOL+4
IE = IE-ICOL+4
920 CALL VSRC(AFN,1000,IXLEN,IST)
IF (IST.EQ.3 .OR. IST.EQ.-6) GO TO 900
TY = IXLEN(1)
WRITE(5,540) TY,(IXLEN(K),K=18,IE)
GO TO 920
900 CONTINUE
999 CONTINUE

3 C *** PRINT ELEVATION FREQUENCY DISTRIBUTION.
454 C IF (IOPT.EQ.2) GO TO 1000
455 WRITE(5,2005)
456 DO 910 I = 1,NEL
457 WRITE(5,2006) I,ELF(I)
458 END
460 910 CONTINUE
461 1000 STOP
462 END

ENTRY/COMMON BLOCK NAMES
EXTERNAL NAMES
GENERAL INFORMATION CONCERNING DATA SOURCE

The NCIC, Office of Research and Standards, Reston, Virginia and the DMATC, Washington, D.C. were contacted in regard to the digital terrain tapes. It was learned that the DMATC prepares two 1° x 1° matrices for each 1:250,000-scale quadrangle map. The \( x, y \) sheet corners and all subsequent readings of each half of a quad map are referenced to an arbitrary coordinate system (ACS). The origin of this ACS is an arbitrary reference point that is different for each 1° x 1° area. The approach used at the ERL is to reference the (\( x, y \)) plate readings directly to the UTM grid and then compute coordinates of points in the UTM system directly from the readings. Thus, an angle correction is required for each 1° x 1° area.

Further discussions revealed that a photographic process is used to produce a map from the 1:250,000-scale series whereby a "contour" line has a "ditch" type depression. The operator of the digital graphic recorder follows this ditch in the actual extraction of contour data. Further processing involves interpolation of a planar nature. Error sources in the DMATC process are resolution (<10 mils) and operator accuracy (less than resolution error).

It was also verified from the DMATC that there is an "edge" matching problem on the right and left of all quad maps and that the data exhibits a "saw-tooth" effect at the top or bottom edges of quad maps. Since the actual extraction of planar data...
(x-y plate coordinate readings in inches) is from a non-square map (latitude-longitude map), then the subsequent transformation of these planar data to the regular shaped UTM coordinate system results in these edge and border problems. These problems have been encountered in the research efforts at the ERL. It should be pointed out that these problems are not encountered if the subsequent analysis programs (such as data base programs) are compatible with the latitude-longitude coordinate system.