THE AUTOMATED REVISION OF TENNESSEE VALLEY TOPOGRAPHIC 1:24,000 QUADRANGLES

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ABSTRACT

For quite some time, the increasing cost of map maintenance has necessitated a move to automated systems. The Tennessee Valley Authority (TVA) Mapping Services Branch (MSB) began to automate its map production in March, 1983, and now, one-and-one-half years later, has succeeded in automating the revision process for its seven hundred seventy-five 1:24,000 national series topographic maps maintained under an agreement with the U.S. Geological Survey (USGS) National Mapping Program. The first example of this process is the Pulaski, Tennessee quadrangle. This quadrangle, as well as the others in progress, was loaded and revised on TVA's Automated Mapping System (AMS), which consists of an Intergraph VAX 11/780 graphic design system and a Gerber 4177 photohead plotter. The revision process is being implemented in three stages: a combined automated and manual process for the first year, completely digital photorevision for the years following, and completely digital full revision using the AMS stereoplotter workstation. By integrating the map revision process with the necessary digital loading, TVA is speeding up its 1:24,000 quadrangle revision as well as creating the digital data that will be necessary for future revisions, related map products, and geographic analysis.

PROCEDURAL FLOW

The automated interim photorevision of 1:24,000 Valley Topographic Maps (VTM) has been integrated into the existing manual process and parallels many manual color separation procedures.

The major requirement for automated revision is that the current version of a quadrangle be available in digital form. For this reason, only revised data that is normally shown in purple and the woodlands overlay were loaded (digitized) into the system during the first year.

First Year Interim Revision

The Compilation and Edit Unit prepared the revision manuscripts as they have for TVA's manual color separation procedures. Using these manuscripts, the operator created a digital map file using Intergraph's

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World Mapping System software. Symbols indicating the four corners of the quadrangle in a polyconic projection were placed in their theoretically correct positions in the graphic file by keying in their locations in latitude and longitude.

After setting up the file, the operators digitized a new woodland overlay and all revisions that were shown on the manuscript, using 59 preassigned logical layers for the various features (See Appendix A). All of the digitized features were symbolized according to USGS specifications for 1:24,000 topographic quadrangles.

Upon completion of the digitizing, a cycle of multi-color pen plots and digitizing edits was conducted by operators on the sheets they had digitized.

Final photoplots were then made on negative film on the Gerber plotter and turned over to the manual Color Separation Unit for registration with the archived separations for each quadrangle.

A particular problem arose in registering the two sets of quadrangle separations: the automated separations did not exactly fit the existing manually produced separations, and registration holes had to be stripped in. The reason for this misregistration was that the separations produced on the AMS were theoretically correct, i.e., all the detail on the quadrangles fit the four corner monuments which were located exactly where they should be in relation to one another, and the scale was exactly 1:24,000. The manually produced separations, however, due to manual production methods, were not as accurate. This made for difficulty in manually deleting content from the old separations and making the exact joins with the purple (revised) data.

After registering the separations, a color proofing and edit cycle was begun, as has been the normal practice.

Present Interim Revision

After the first set of 12 interim revision separations were produced, loading of the next set of quadrangles scheduled for revision was started. Revision of these maps is being accomplished in a similar manner to the partially automated method; however, all of the features, except for text, are available in digital form, so that all revision work, including deletion of features, is being done on the AMS. As in the first phase, symbolization of all features adheres strictly to USGS specifications.

After a digitizing edit, negative separations are plotted for all of the features (except for text) that will appear on the printed map. (The type separation is still prepared manually because of system limitations.) The generation of all of the linework from the AMS has resolved the problem of misregistration with manually prepared materials.

A feature of the Gerber photohead plotter that speeds up production is the 28-pin registry system. Pins are available to plot three sizes of separations using a Misomex punch, and to plot four 1:24,000 quadrangle separations during one run when the Gerber multiple plot software is used.

Quadrangle Loading

A quadrangle must be loaded into the system before a fully automated revision can be accomplished. In most cases, an operator obtains the set of negative separations for that quadrangle which has been supplied by the USGS Eastern Mapping Center. When a set of negatives for a quad is not available, the archived paper print is used. Source material is digitized at its original scale of 1:24,000.

A World Mapping System file is set up as in the above revision procedure. (All of the VTM quadrangles are in the polyconic projection.) Following this, the digitizing table surface is activated. Most distortion is resolved through the digitizer transformation (a least squares fit), which causes the actual corners of the quadrangle to match their theoretical positions as shown on the graphics screen. The relationship between the actual and theoretical corners is applied to all data that is digitized.

Three standard files are attached to any VTM graphic file: a cell (symbol) file, a user command index file (which allows the operators easily to access World Mapping System functions), and a color lookup table, which defines the color used for each logical level. The colors have been defined to represent as closely as possible the colors shown on TVA's standard opaque color proof. The background is a light grey to represent the paper and to allow the use of black for map features.

Culture is the first major category to be loaded. Cultural features are separated onto 59 logical levels. Sixty-seven symbols ("cells" in Intergraph terminology) have been created for point, line, and area features. The symbols meet USGS specifications when they are photoplotted and provide accurate representations on the graphic screens for the operator; they are used to represent most point features, such as vertical and horizontal control monuments, school flags, and cemetery crosses. Road casings are created by digitizing either a centerline or one side of a road casing, and then copying the line in a parallel mode as many times as necessary. First and second class road fills are created from digitized centerlines by using a linear symbol as a "pattern" for that line. The outlines of area features are digitized and, depending on the particular feature, the outline is either used to make a peel coat, e.g., for woodlands, or it is defined as a shape and filled with an area pattern on the AMS, e.g., for disturbed surfaces. Drainage is the second feature category digitized. Although this does not present the same problem as culture with respect to symbolization, special treatment is needed for springs and open water areas. For springs, a symbol must be used, whereas for open water, only the outline is digitized and an open window negative is created using the photoplotter and peel coat.

With the exception of depressions, symbolization is not a concern with the third category of features, contours. The sheer volume of data, however, is a major problem. The digitizing of contours is responsible for approximately one-half the time required to load a complete quadrangle. The total time for digitizing a quadrangle in the Tennessee Valley is from four to six weeks. After some experience with contour digitizing using stream mode (where the system is continually being fed data points as long as the cursor button is being held down and moved, provided the new point meets distance and deflection angle criteria), a decision was made to use curve strings to represent contours. This mode of digitizing was easier for the operators, since only one data point is fed into the system each time the cursor data button is pressed. A curve string, as opposed to a line string, adds two extra points to each end of each string. These two points are not visible, but they are used to apply a spline curve to the string of points when "slow curve" display is turned on. Therefore, the number of points needed to represent a contour properly is less than with a line string. On recent quadrangle loads, the elevation text has been added to the "brown text" logical layer.

Text is the one category of information that, for the most part, is not included in the digital file. This is due to the difficulties in creating publication quality type fonts on the AMS.

EVALUATION

<u>Accuracy</u>

The accuracy of the automated revision process may be evaluated at two stages of production: when the data are entered into the system and when separation negatives are plotted. These are the two points where inaccuracies due to digital processing would most likely be introduced.

The hard copy produced by the photohead plotter has been found to be more accurate than manually produced products covering the same geographic area. This has been determined by measuring the distances (using an Invar steel scale) between points of known location, such as grid intersections and quadrangle corners. As previously mentioned, this greater accuracy and precision created a registration problem during the first year interim revision process.

Cartographic data are entered into the system by manual digitizing using a backlighted table with .001 inches resolution and a hand-held cursor with a 2X magnification. A well-trained operator using this equipment can create an accurate digital copy of the features on the source materials. However, due to the geographic accuracy of the system (through World Mapping), some slight positional shifts from the original materials do occur. For the purpose of revising VTM quadrangles and producing publication quality separation negatives, TVA has been well satisfied with the accuracy of loaded quadrangles. Data that are added to the digital file as a part of the revision process are digitized from a revision manuscript produced by the Compilation and Edit Unit This digitizing process is very much like the existing manual process of scribing features to be added from a revision manuscript. Any inaccuracies introduced in this process would be the same for either the manual or automated revision technique.

Cost Comparison

Cost figures are available only for the first year interim revisions. The quadrangles being revised this year in a completely digital mode are not yet far enough along to permit a cost comparison.

The first year interim revision process costs averaged $1,500 per quadrangle for the automated operation. Compilation and edit cost averaged $2,100, and the manual color separation work cost approximately $3,500. This made the total average cost per sheet $7,100. The average cost for a quadrangle revised by manual methods has been $6,000. Therefore, the first year revision process cost an extra $1,100 per map.

Two questions should be asked concerning the higher cost for a partially digital product: why was the cost higher, considering that "digital mapping" is supposed to be a money saver, and what extra benefits, if any, were derived for the extra money spent. In the authors' opinion, the primary causes of the increased cost were the need to include the extra step of painstaking manual matching of the separations, and the difficulty encountered in properly registering the digitally produced revision separations with the existing set of manually produced negatives, and the concomitant painstaking manual matching of features. The extra labor and reproduction shop charges were significant. The benefit that TVA derived, in addition to refining its revision procedures, was that part of each quadrangle revised was loaded into the AMS. When those same quadrangles are fully loaded into the system, that part of the data will already have been digitized.

Time/Cost For Loads

During this and the previous fiscal year, TVA has been loading the first set of 27 quadrangles, 12 of which will be digitally revised in a full production mode this year. The time required to load a quadrangle has ranged from four to six weeks depending on the complexity of the data. This has resulted in an average cost of $4,500 per quadrangle.

The cost of loading a 1:24,000 quadrangle through manual digitizing is significant and is being gradually lowered by the writing of programs designed to speed up specific tasks. The extra cost of manual digitizing is, to some degree, lessened by the fact that TVA has tried to avoid purchasing more equipment than necessary, since capital depreciation on any such equipment must be paid out of operating funds.

An evaluation has been presented only for the first phase of digital revision on TVA's AMS. The production of a completely digital interim revision prototype, Pulaski, Tennessee, has shown that publication-quality line work can be produced digitally. By the end of the 1985 calendar year, enough quadrangles will have been processed through the digital revision procedure so that the costs can be evaluated. We fully anticipate that they will be significantly reduced from the present level as the implementation phase continues for this revision method.

FUTURE PRODUCTION

Raster Scanning
TVA's MSB has looked at scanning systems and does not believe that their cost (in terms of annual depreciation) can be justified or supported by its operating budget. However, discussions are underway with other government agencies for scanning services to be provided on a reimbursable basis. From the available information, it seems that this method of data capture would be most effective for contours and drainage.

Attributes
Attribute ("intelligent") information is not presently being attached to graphic elements in the AMS VTM files. Once the graphic part of the automated revision process is smoothed out, attribute data bases will be created for these files.

Compilation
In the near future, we will attempt to compile interim revisions at an AMS workstation to avoid the present repetitive process of manually creating a revision overlay and going over the linework a second time in order to digitize it. This should reduce the revision cost by removing unnecessary procedures.

Text
The omission of most text from the VTM files is mostly due to the limited capabilities of the AMS in this area. Based on inhouse testing, the authors feel that text of acceptable quality can be generated by the photohead plotter. However, acceptable font and spacing problems must still be addressed on the Intergraph part of the system. Work on text will be continuing inhouse to try to eliminate the need for a manual type stick-up operation on VTM quadrangles.

Three Dimensional Files
Although there are advantages to storing cartographic data in three dimensional files, the difficulties of digitizing "planimetric" features in 3-D, as well as the

inaccuracy of the elevations, have persuaded us to continue to use two-dimensional files. For certain non-VTM related projects that are worked on the stereoplotter workstation, however, three-dimensional files will be created and used to generate final map products.

Contours with Tagged Elevations

Even though the decision has been made to remain with two-dimensional files, it is still advantageous to maintain elevation information at least for the contours on a quadrangle. If contours are logically "tagged" with their elevations, they can be used as input to digital terrain modeling packages. Work is underway on a contour digitizing program that will automatically tag contours with elevations as they are being digitized.

SUMMARY

TVA's Automated Mapping System was purchased with the expressed intention of lowering the cost of revising TVA's map series, one of them being the seven hundred seventy-five 1:24,000 Valley Topographic quadrangles maintained under agreement with the USGS National Mapping Program. Less than two years later, TVA has produced a digital interim revised quadrangle that meets all USGS specifications for the printed 1:24,000 topographic map series. To the best of our knowledge, this is the first such quadrangle produced in the United States.

Appreciable cost savings are anticipated with the production of completely digital interim revisions. Further cost reductions will be achieved through customized programming and increased use of newer technologies, e.g., raster scanning and editing. Benefits beyond a lowered cost for map revisions are being and will continue to be realized because the quadrangle is in digital form. The availability of an accurate digital reference base map is invaluable for use in the production of project-specific special-purpose maps, as well as allowing for the creation and use of digital terrain models.

APPENDIX A

Tennessee Valley Authority
Topographic Mapping (1:24,000)
Level Assignments - Cartographic Files

Level	Feature	Separation Color
1	First class casings	Black
2	Second class casings	Black
3	Red road fills	Red
4	Third class casings	Black
5	Fourth class roads	Black
6	Wagon, jeep, and foot trails	Black
7	----------------------------	
8	Active railroads	Black
9	Inactive railroads	Black
10	Crossings (Bridges, tunnels, etc.)	Black
11	Masonry dams, locks, jetties	Black
12	----------------------------	
13	First class buildings	Black
14	Second class buildings	Black
15	Public service buildings	Black
16	Mines or quarries	Black
17	Transmission lines	Black
18	Pipelines, telephone lines	Black
19	State boundaries	Black
20	County boundaries	Black
21	Corporate boundaries	Black
22	Reservation boundaries	Black
23	Small parks, golf courses	Black
24	Cemeteries	Black
25	Horizontal control points	Black
26	Vertical control points	Black
27	Boundary and miscellaneous monuments	Black
28	Levees and miscellaneous hachuring	Brown
29	State Plane labels	
30	GLO lines and monuments	Red
31	Foreshore and offshore features	Black
32	Index contours	Brown
33	Intermediate contours	Brown
34	Supplemental contours	Brown
35	Neatline, State Plane and Carter ticks, longitude and latitude info	Black
36	UTM	Black
37	Strip Mines and intricate surfaces	Brown
38	Open water (double line drainage)	Blue
39	Single line drainage	Blue
40	Intermittent drainage and ponds	Blue
41	Water wells and springs	Blue
42	Swamps	Blue
43	Channel lines	Blue
44	Lands subject to inundation	Blue
45	Field and fence lines	Red
46	Urban areas	Pink
47	Woods	Green
48	Other vegetation	Green
49	Purple revisions (other than text)	Purple
50	Black miscellaneous separation	Black
51	Blue miscellaneous separation	Blue

52	Brown miscellaneous separation	Brown
53	Red miscellaneous separation	Red
54	Unclassified buildings	Purple
55	Purple text	
56	Black text	
57	Blue text	
58	Brown text	
59	Red text	
60	-----------------------------	
61	-----------------------------	
62	-----------------------------	
63	Photoplot template	