Skydusky Hollow Photogrammetric Mapping Project

by Hillary Minich

Abstract. The Skydusky Hollow Photogrammetric Mapping Project is the first part of a project to connect two surveys, one above ground and the other below ground. The ultimate goal is to make a bilevel map of Skydusky Hollow, Virginia, which contains a 20-mi. cave system. The map will be of great service to the VPI Grotto of the National Speleological Society and the farmers of the area. It will show the relationship of the coves in the system with respect to each other and the overlying topography. This report describes the compilation of the topographic map, as well as describing the establishment of the field control necessary to compile the map by photogrammetry, locate the eight cave entrances and their resurgence spring, and orient and adjust the lower-order cave surveys. It was planned from start to finish as an independent study project, in which all of the map compilation and much of the surveying was performed by a surveying and photogrammetry student working on her undergraduate degree.

Introduction

Background

Skydusky Hollow is located in a remote section of Bland County, Virginia, and contains the largest known cave system in the state.* It is an area of extreme interest to the members of the VPI Cave Club, a Grotto of the National Speleological Society (NSS), who have been mapping, dye-tracing, and studying the geology and biology of the eight known caves in the system for the past 20 years. They have mapped approximately 20 mi. of underground passage thus far.

The landowners of the area, predominantly sheep and cattle farmers, are interested in the system as a potential water supply for themselves and their livestock. Scarcity of surface water due to its sinking into underground streams and caves is characteristic of all karst areas such as Skydusky, putting the farmer at an extreme disadvantage during drought conditions.

A large-scale topographic map of the area including the cave entrances, the resurgence spring, and planimetric features of local interest superimposed on the cave surveys would be extremely useful to both interested groups. In addition to showing the position of the underground streams relative to the surface topography, a bilevel map would show the precise relative positions of the caves in the system. For many years, the concerned groups have expressed the need for such a map.

Objective

Mapping the area seemed as though it would be interesting, challenging, and a very worthwhile experience for an undergraduate student. Therefore, a photogrammetric mapping independent study project was developed as part of the author's civil engineering course work at Virginia Tech.

The objectives of the project were to establish the necessary control networks and then photogrammetrically compile a 10-ft. countour interval map of Skydusky Hollow. The finished map is illustrated in Figure 1. The map was to show the eight cave entrance positions, the resurgence spring position, and the planimetric features of local interest. An article about the project, to be published in

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At the time of the project, Miss Minich was a senior bachelor of science degree candidate in the Department of Civil Engineering, Virginia Polytechnic Institute and State University, specializing in surveying and photogrammetry. She was a student member of ACSM/ASP, and was an active member of the VPI Grotto of the NSS (National Speleological Society), serving as treasurer during the 1983/84 academic year. Miss Minich is presently employed by Intergraph Corporation in Huntsville, Alabama.

*Note: These caves are on private land and are closed to the public in the interest of cave conservation, safety, and landowner relations. For more information, contact Hillary Minich at 190 Shelton Road, No. 204, Madison, Alabama 35758.

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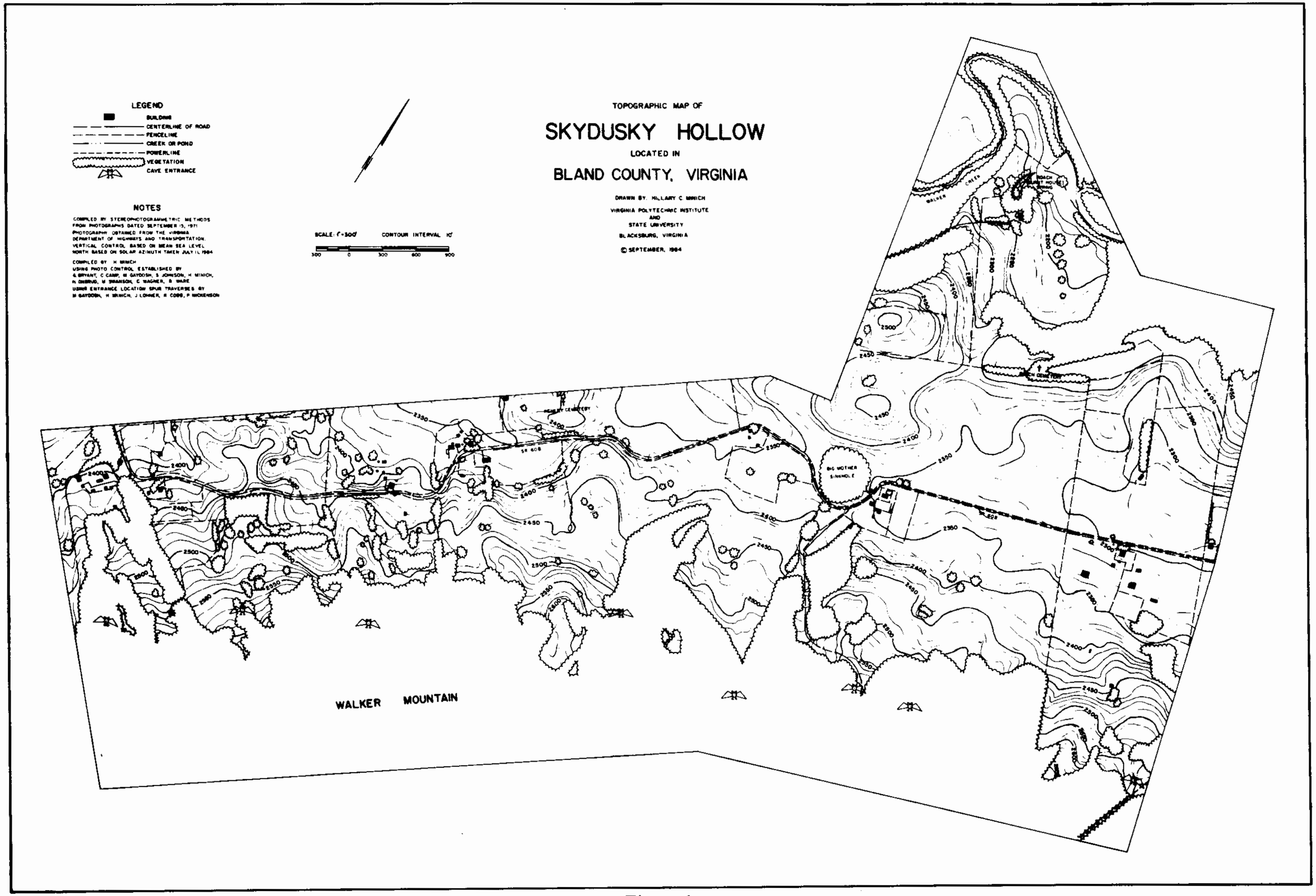
TOPOGRAPHIC MAP OF
SKYDUSKY HOLLOW
LOCATED IN
BLAND COUNTY, VIRGINIA
DRAWN BY: HILLARY C. MINICH
VIRGINIA POLYTECHNIC INSTITUTE
AND
STATE UNIVERSITY
BLACKSBURG, VIRGINIA
© SEPTEMBER, 1984
LEGEND
BUILDING
CENTERLINE OF ROAD
FENCELINE
CREEK OR POND
POWERLINE
VEGETATION
CAVE ENTRANCE
NOTES
COMPILED BY STEREOPHOTOGRAMMETRIC METHODS FROM PHOTOGRAPHS DATED SEPTEMBER 15, 1971
PHOTOGRAPHY OBTAINED FROM THE VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION.
VERTICAL CONTROL BASED ON MEAN SEA LEVEL
NORTH BASED ON SOLAR AZIMUTH TAKEN JULY 11, 1984
COMPILED BY H MINICH
USING PHOTO CONTROL ESTABLISHED BY
BRYANT, C CAMP, M GAYDOSH, S JOHNSON, H MINICH,
ONSRUD, M SWANSON, C WAGNER, B WARE
USING ENTRANCE LOCATION SPUR TRAVERSES BY
M GAYDOSH, H MINICH, J LOHNER, R COBB
SCALE: 1"=500'
CONTOUR INTERVAL 10'
300 0 300 600 900
BIG MOTHER SINKHOLE
SR 608
WALKER CREEK
WALKER MOUNTAIN

Figure 1.

This paper—the winnner—describes a project which was submitted for consideration for the and National Society of Professional Surveyors (NSPS) Student Land Surveyors Project of the Year Award for 1984.

the quarterly VPI cave club journal *The Tech Troglodyte*, was to accompany the map.

Field Control Survey

Existing Control Situation

Because Skydusky Hollow is in such a remote area, no usable control existed. There is a triangulation station, High Rock, on top of Walker Mountain, overlooking the cave area, but the station was effectively inaccessible due to time and manpower constraints. USGS map reference elevations exist at two points on SR 608. The road runs through the middle of the project area and parallel to Walker Mountain. By default, these points were used to reference the survey to the mean sea level datum.

The lack of usable control coupled with time and manpower limitations meant that it was impossible to tie the survey into a larger network such as the state plane coordinate system. This did not adversely affect the project, however, because the primary concern was the precise orientation of the two surveys with respect to each other: a low-order Brunton-and-tape survey existing below ground, and a high-order survey which was to be established above ground.

Control Needed

The objective of the survey was to establish enough horizontal and vertical control to enable the orientation of two stereomodels of the area and the subsequent compilation of a 10-ft. contour interval topographic map.

Basic control network. The basic horizontal control network design consisted of three points (A, B, and C) set on the highest hilltops opposite Walker Mountain. These primary points were situated so that the road and all the photocontrol stations near the caves would be visible. (See Figure 2.)

The necessary basic vertical control was established by a level line surveyed along SR 608. Several temporary benchmarks and the two USGS map elevations were referenced in this level line.

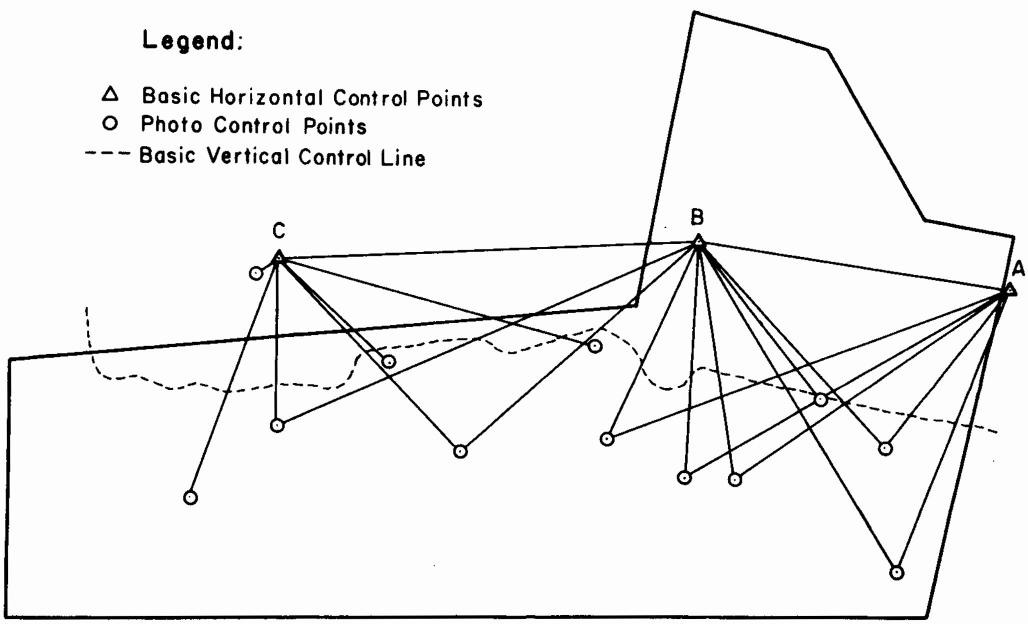

Figure 2. Project Control Networks.

Photo control. Photo control was established by intersection and side shots as necessary to control the stereomodels adequately.

Entrance location traverses. Spur traverses connected to the basic control were needed to reference the cave entrances. The cave entrance locations are in dense forest and underbrush that made them impossible to see from the aerial photography.

Control Survey Methods

The plan was to put a basic framework (backbone) through the center of the project area and then establish the photo control using lower-order surveys connected to the basic control.

The five students in Applied Surveying Problems (the summer surveying lab at VPI), two graduate teaching assisants, and one professor, established all but the auxiliary control as one of the class projects. A tight schedule allowed only 3 days to complete the fieldwork and office computations. Auxiliary points not required for photogrammetric compilation were surveyed at a later date.

Horizontal control. Basic horizontal control points, A, B, and C, were located so that they would be intervisible as well as visible from as many of the photo identifiable points as possible. The three points were then occupied by 1-sec. theodolites, and infrared EDMI (electronic distance measurement instruments). Solar observation at points B and C were used to orient the network and provide azimuth closure. The observed angles and distances were used to locate points A, B, and C precisely. From the primary points, additional observations were used to establish vertical control by trigonometric leveling and to locate some of the photo control points by intersection.

Vertical control. Primary vertical control was established by an approximately 2-mi.-long, double-rodded level line down SR 608 using an automatic level and two Philadelphia rods. Temporary benchmarks were set at photo identifiable points also visible from at least one (two, if possible) of the horizontal control points. USGS map elevation points at two road intersections were used to establish a reference mark to the datum

Where possible, double-rodded leveling elevations were compared and checked with trigonometric leveling to horizontal control points.

Photo control. Since we had to use existing photography, photo control was designed using natural targets. We attempted to obtain the best geometric strength possible for the two models with at least three horizontal and four vertical control points in each model. The horizontal points were established by distance intersection from the basic control using EDMI. This procedure saved time compared to traversing or angle intersection methods only. Trigonometric and double-rodded leveling were used for most vertical control, but barometric leveling was employed to establish vertical control in some remote corners of the photogrammetric stereomodels.

The majority of the photo control points were also used as beginning points by the entrance location spur traverses. Thus, these photo control points were positioned as near to the cave entrances as possible without impairing the visibility of each point from two of the basic horizontal control points.

The 3-day time allotment and the fact that there were only five students working on the data reductions severely limited the amount of control that could be established. However, the objective of establishing adequate control was successfully met, and a least squares adjustment of the entire network was completed.

Entrance Location Spur Traverses

The cave's entrances could not be located photogrammetrically because the forest and underbrush was in full leaf at the time of the photography. Therefore, it was necessary to traverse from the nearest available control points to the cave entrances.

Several other members of the VPI Cave Club assisted in running the spur traverses. Stadia were used where long shots were not possible due to visibility problems encountered in the forest and thick underbrush. A theodolite with attached EDMI was used when long unobstructed shots were feasible. When possible, the survey was tied directly into the entrance station of the underground survey at each cave. If the underground survey station could not be identified, an appropriate stationary boulder near the entrance was chosen and an "X" was chiseled there to serve as a temporary entrance station until the existing one could be located. Detailed station descriptions were written and photographs of each station were taken to enable identification of the entrance stations used. This will be an extremely valuable aid when connection of the above- and below-ground maps is begun.

The traverses were run prior to and during the map compilation process. Leapfrogging the EDMI and reflectors and using a programmable computer to compute the entrance coordinates saved some time, but inclement weather and lack of people with surveying experience made this the most time-consuming part of the project.

Photogrammetric Mapping

Model Setup

The best available photography of the Skydusky Hollow area was taken at an average flying height of 8,409 ft. above the terrain with a 6-in. focal length camera. The scale was 1:16,800 (1 in. = 1400 ft.). The east-west flight line orientation was not parallel to any of the project boundaries. Two stereomodels were needed to compile the map, and part of the mapping area was in a corner of each model as shown in Figure 3. Accordingly, most of the photocontrol was in the corner or edge of each model, making the manual plotter orientation process unusually difficult and tedious. A Zeiss C-8 stereoplotter was used to compile the map. The model scale in the plotter was set at 1 in. = 600 ft.; a 1 in. = 300 ft. map scale was obtained using a 2:1 plotter-to-table gear ratio.

Compilation Procedure

Before beginning compilation, a 1 in. = 300 ft. computer plot of the control point field was generated on the University Calcomp drum plotter. The base map was put on the plotter table and oriented so the plotted control points corresponded to those in the stereomodel. A sheet of mylar was then taped on top of the control sheet.

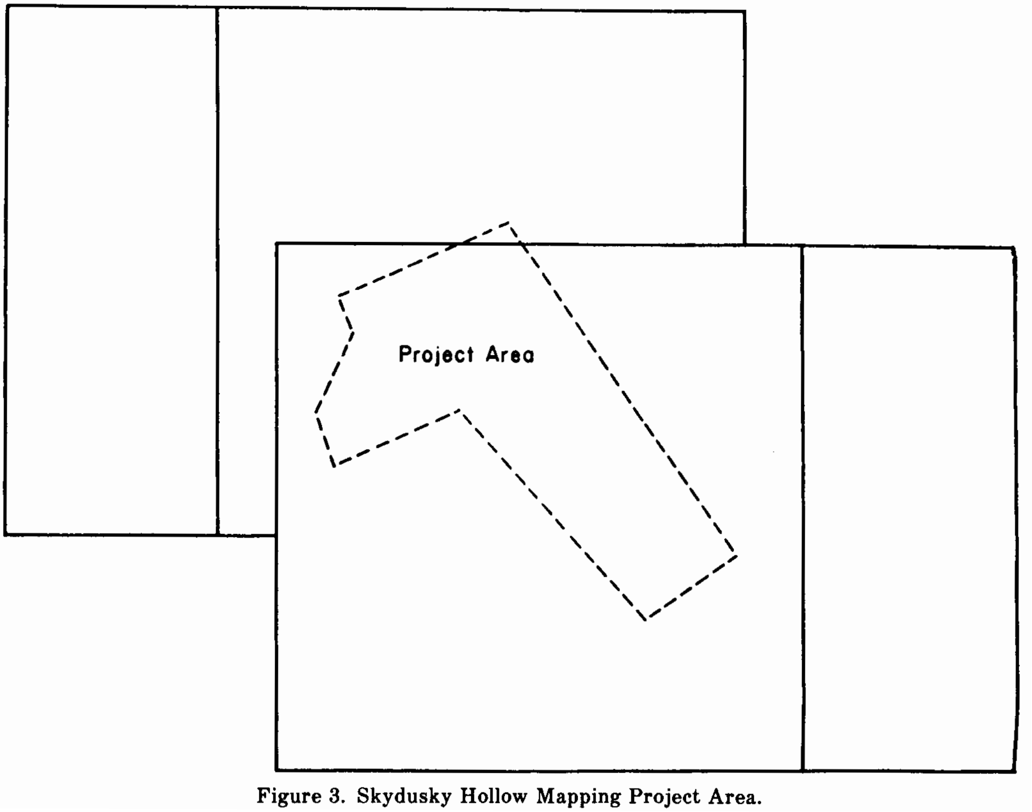

Figure 3. Skydusky Hollow Mapping Project Area.

Compilation of each model began with plotting planimetric features such as buildings, roads, and vegetation. The cave entrance coordinates were plotted directly on the manuscript as they were computed from the spur traverses.

After finishing the planimetric features, the contours were compiled. The first contours were plotted by dropping spot elevations and interpolating to determine the contour position. However, after approximately 2 days of practice, contours could be followed accurately and traced directly onto the manuscript using the floating mark.

Fortunately, another surveying student who had participated in the field surveys, helped to darken contours and perform other drafting chores on the coordinatograph as the map was compiled. This procedure saved much time and effort, but even with the help, the contours took much longer to plot than the planimetric features.

An inked copy on mylar was traced from the stereoplotter manuscript and a final map product was prepared. Figure 1 is a photographic reduction of the original 1 in. = 300 ft. map sheet.

Summary and Conclusions

The proposal for the project was first discussed with Dr. Johnson [Dr. Steven Johnson, professor, Dept. of Civil Engineering, VPI & SU], and search for the photography commenced near the end of March 1984. The map manuscript was completed by the end of September and the report by the middle of October. The finished map was very well received by the VPI Cave Club. Fifty copies of the map were made for the cave club and five copies were distributed to the landowners. An article summarizing the project was published in the winter issue of *The Tech Troglodyte*.

The author gained a vast amount of knowledge during the course of this independent study project. Few undergraduate surveying and photogrammetry students have the opportunity to plan and execute from start to finish an entire mapping project, which including finding the best imagery, planning, participating in the control survey, and compiling the map. The Skydusky Hollow Photogrammetric Mapping Project was an extremely successful educational experience and valuable practical project.

Status of Project as of January 1, 1985

The station descriptions and copies of the entrance station photographs have been given to the VPI Cave Club. Copies of the map, entrance coordinates, and station descriptions have also been given to the person coordinating the underground survey data. As soon as possible, the above-ground and below-ground maps will be digitized on a computer graphics system and superimposed to produce a final cave club product. Although the overall project is not yet complete, the objectives of this project have been successfully met.

ACKNOWLEDGMENTS

The success of this challenging project would not have been possible without the help of the friends and associates whom I would like to recognize and thank. Dr. Steven Johnson was my advising professor on the project; Matt Swanson, Charles Wagner, George Bryant, Cass Camp, Mike Gaydosh, Bill Ware, and Professor Harlan J. Onsrud helped establish the necessary photo control network; Mike Gaydosh, John Lohner, Richard Cobb, and Pat Nickenson helped run the spur traverses up to the cave entrances; and Mike Gaydosh spent many hours at the plotter table assisting me in the compilation of the map. I would also like to thank the landowners of Skydusky Hollow for their cooperation, hospitality, and patience. ■