

*APPLICATION OF PHOTOGRAMMETRY  
TO  
MAPPING FOR HIGHWAY LOCATION STUDIES*

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TECHNICAL PAPER

APPLICATION OF PHOTOGRAMMETRY TO MAPPING  
FOR HIGHWAY LOCATION STUDIES

by

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INTRODUCTION

Photogrammetric surveying using vertical airphotos, as it is practiced by many private and public agencies, has proven itself to be a quick and reliable means for highway planning and design. Its success to date and its promise of greater reliability and refinement in the future due to improved cameras, films, airplanes, and other photogrammetric equipment should warrant a greater expansion of its use.

The California Division of Highways is an example of an agency which has used photogrammetric surveys widely for preliminary and final highway location surveys. They have abandoned ordinary plane table mapping for preliminary surveys because it was found to be less accurate than photogrammetric mapping (2). The California Division of Highways has used location maps made by photogrammetric means to calculate earth volume quantities when calling for bids on construction contracts. They have found that on large projects for which photogrammetric maps were made by reputable firms, and for which they checked the earth volumes after construction by ground surveys, that the original volumes were in error by 3.8 percent at the most. This small error they believe to be very reasonable considering the fact that they believe they can only estimate shrinkage and swell to within 5 percent.

Because airphotos record all visible ground features, photogrammetric maps can usually be relied upon to be more complete than a map made by conventional methods. A photogrammetric map will depict completely all the topographical and cultural features which have to be

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considered in selecting a highway alignment. Factors such as cultural obstacles, natural obstacles, land use, drainage pattern and slopes, density and nature of land cover are all readily apparent.

Photogrammetric maps can be made to whatever scale may be needed if the photogrammetrist has access to airphotos of appropriate scale and a precision plotting machine is available. For preliminary design work, a scale range of from two hundred feet-per-inch at a five foot contour interval down to five hundred feet-per-inch with a ten foot contour interval could be used. A map for a final location survey and contract plans would probably use a scale of from one hundred feet-per-inch with a five foot contour interval up to as large as fifty feet-per-inch with a two foot contour interval.

#### DEFINITIONS

Before discussing the subject any further, a definition of some terminology is necessary to make clear what some of the words used by the photogrammetrist mean.

**Photogrammetry:** It is defined by the Manual of Photogrammetry (3) as "the science or art of obtaining reliable measurements by means of photography." This use of aerial photography supplies a quantitative type of information.

**Aerial Photography Interpretation (Airphoto Interpretation):** This term is often confused or included with the term, photogrammetry. This is a qualitative type of study of aerial photographs. The highway engineer would make use of interpretative procedures to differentiate soil types, rock types, drainage conditions and such things as land use. Airphoto Interpretation and Photogrammetry are interrelated and use is made of each art in the carrying out of the other.

**Stereoplotter:** This is an instrument which will form a three dimensional model of an object by the intersection of rays from photographs taken of the object from two different camera positions.

**Picture Control Points:** These are easily identified objects or positions in photographs which have been located on the ground and for which elevations are taken in the case of vertical control points, or between which distances are measured accurately in the field for horizontal control points.

#### PURPOSE

This report is intended to cover the mapping phase of a thesis project which was carried out for the purpose of making a reconnaissance and a preliminary design study of a proposed route for an Interstate Highway at New Albany in southern Indiana. It is intended to report on the procedures and methods used in execution of the mapping phase and to report on the accuracy of the maps produced.

#### SCOPE OF THE WORK

Photography of a section of the proposed route of Interstate Highway No. 64 across the Knobstone Escarpment at New Albany was supplied by the Indiana State Highway Department. This photography, which was taken at a scale of 800 feet-per-inch with an 8 1/4 inch focal length lense, was used to make contact prints and glass diapositive plates for use in a Kelsh Stereoplotter. The Kelsh plotter enlarged the photography four diameters so that the mapping scale was 200 feet-per-inch. The contour interval of the map was ten feet.

Before mapping could be carried out, a study of the map area was necessary. This was done in order to become familiar with the area, to



select possible preliminary center lines for further study, and to determine what control surveys were present and what additional ones were needed.

It was necessary to go to the mapping site and survey additional vertical, horizontal, and coordinate control for mapping and map assembly purposes.

In order to have an independent check of the photogrammetric mapping accuracy, an Indiana State Highway Department crew ran a check profile for 7,000 feet along the center line of Old Hill Road.

#### HIGHWAY DESIGN DIVIDED INTO STAGES

Similar to most types of design problems, highway design is best divided into phases or stages. This enables the planner to make the most economic use of maps and equipment at his disposal. Design of highways is usually divided into three or four stages by most writers (1 and 5). Figure 1 indicates the four stages recommended by Pryor (5). Figures 2 and 3 indicate the type of map and scales considered suitable for reconnaissance and design purposes (1).

After studying the Knobstone Escarpment problem and knowing the scale of photography available, it was decided to use three design stages. These stages were:

(1) Reconnaissance of an Area to Select Alternate Routes Stage: To carry out this stage of study, small scale photography of around one inch per mile and small scale topographic maps such as the United States Geological Survey (U.S.G.S.) 7 1/2 minute quadrangle sheets with a scale 2,000 feet-per-inch are suitable. For this project, the above were available and were supplemented by highway plans and profiles, highway route maps, New Albany city maps, various U.S.G.S. notes and United States



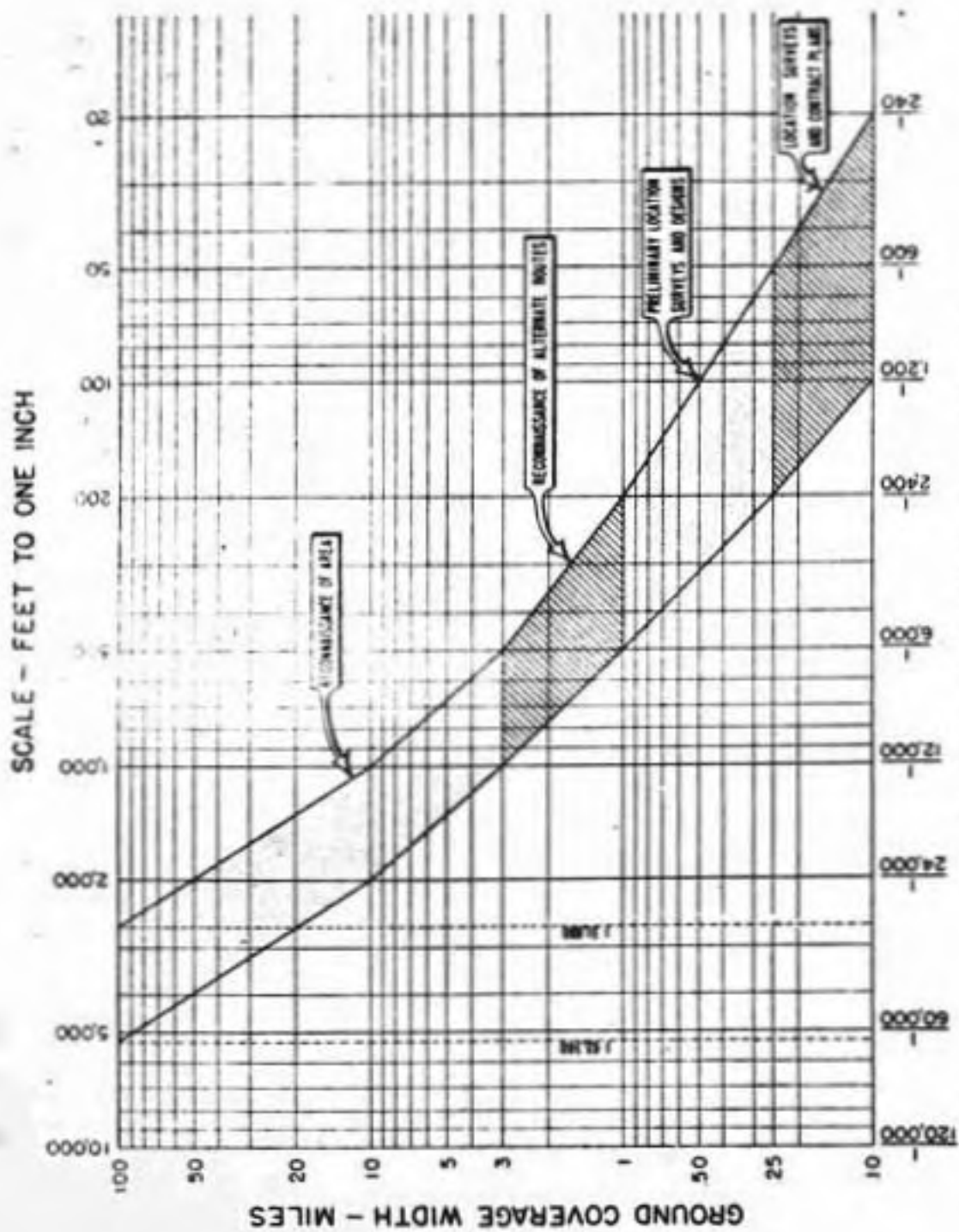




FIG. 2 PHOTOGRAMMETRIC RECONNAISSANCE MAP

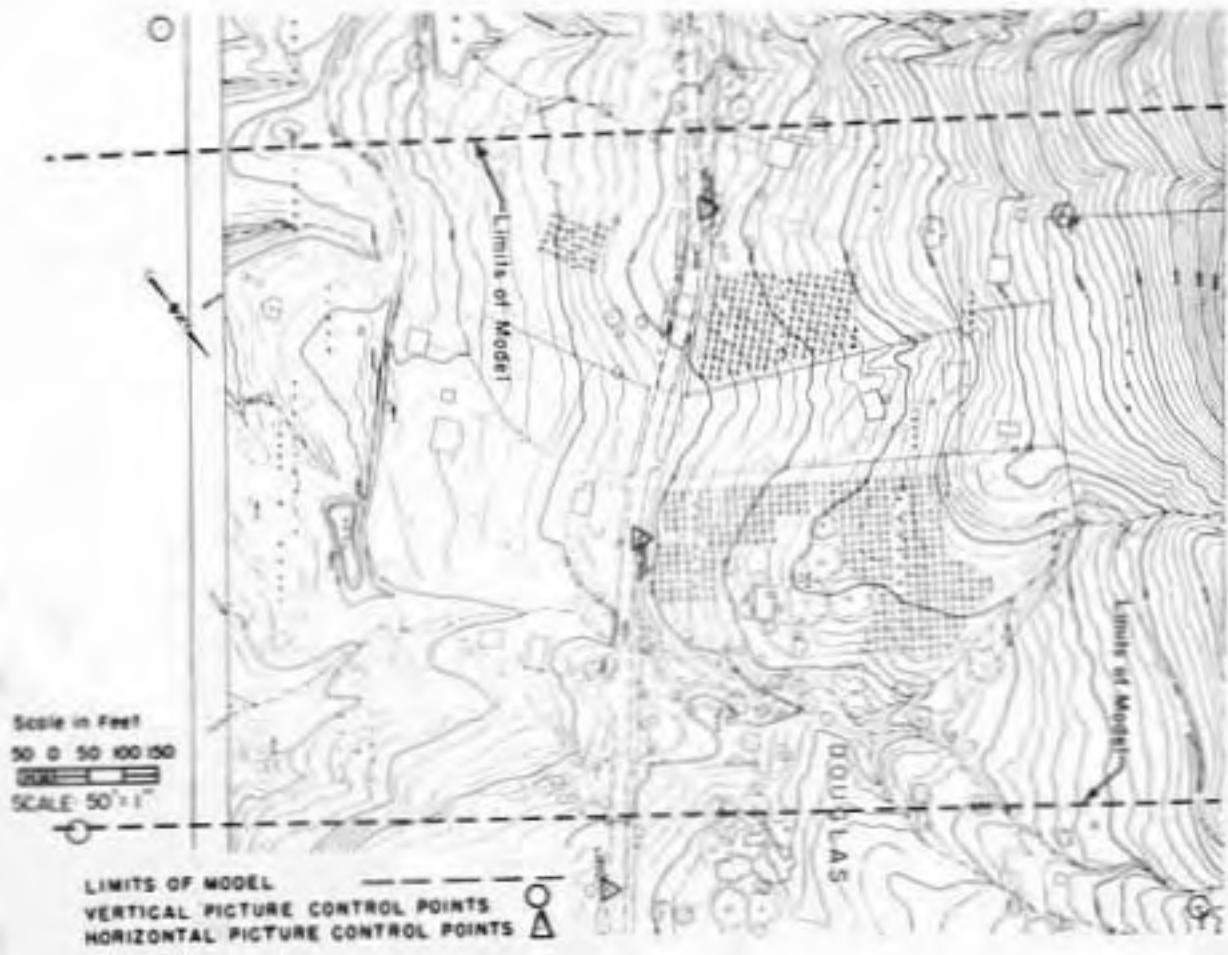


FIG. 3 PHOTOGRAMMETRIC DESIGN MAP

Coast and Geodetic Survey (USC&GS) notes and maps, and field trips into the area. The proposed routes in Figure 4 were selected during this stage of study.

(2) Preliminary study of Selected Routes Stage: This work is usually done with intermediate scale photography and maps. A mosaic of the 800 feet-per-inch photography was made and studied as shown in Figure 5. The photographs were used with the Kelsh plotter to make a map at 200 feet-per-inch which covered an area 12,000 feet wide by 21,000 feet long. This map was then used to make horizontal alignment maps and profile maps using Interstate standards of alignment. Figure 6 shows a profile made from the photogrammetric map.

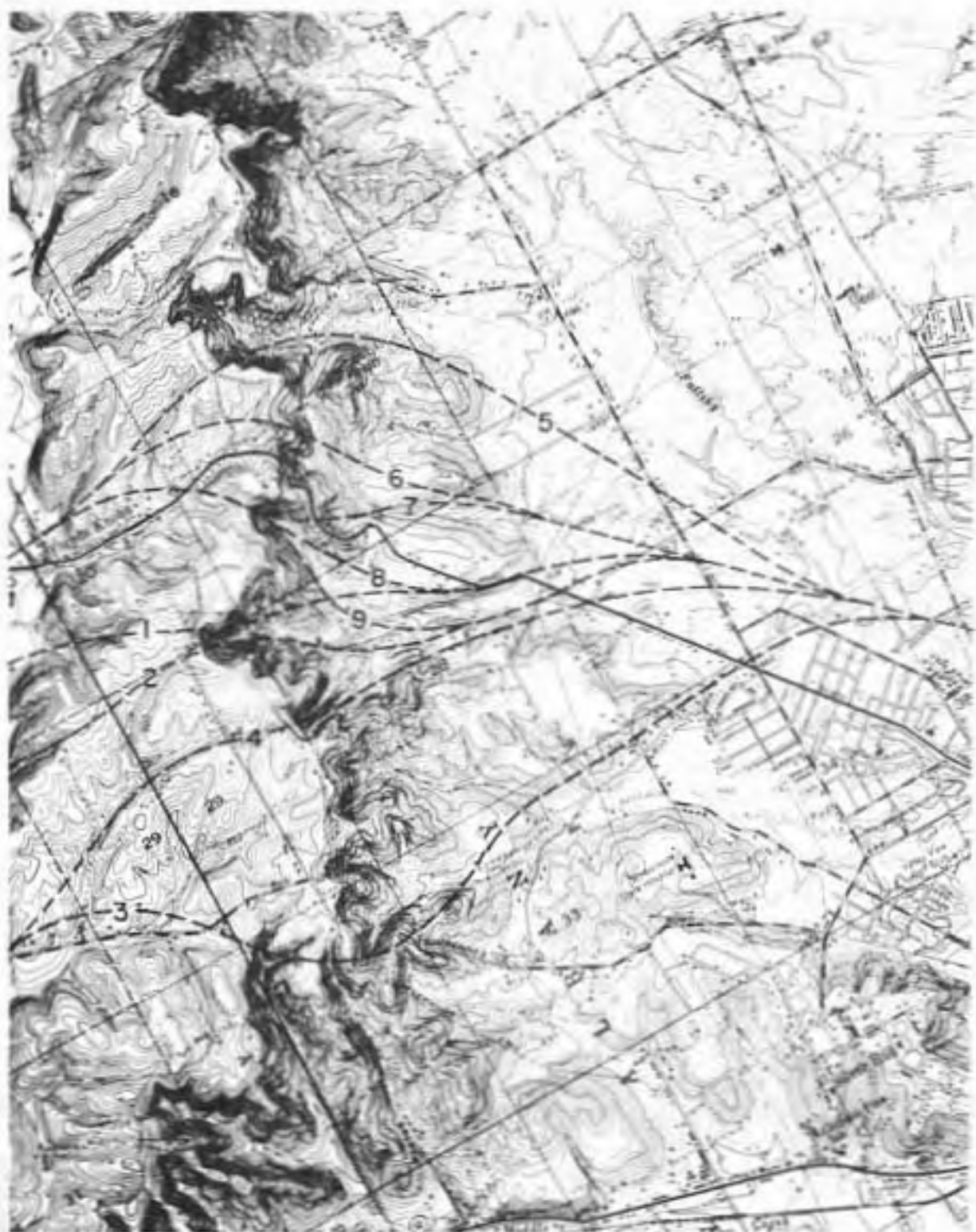
(3) Final Stage: Maps made photogrammetrically at scales of 100 to 40 feet-per-inch should be used for final design or conventional surveys establishing the center line, and taking cross sections notes would be necessary for this stage. Neither of these procedures was followed through, as this was outside the scope of the problem.

## PRELIMINARY DESIGN MAPPING

### Mapping Control Surveys

In order to plot the stereo-models in the Kelsh plotter, it was necessary to survey in the field a minimum of six picture vertical control points per model and to tape two horizontal distances between picture points in each model.

Use was made of city, highway, and state highway bench marks to obtain approximately eight vertical control points for each of the thirteen models plotted.



RECONNAISSANCE STUDY OF ALTERNATE ROUTES

FIG. 4

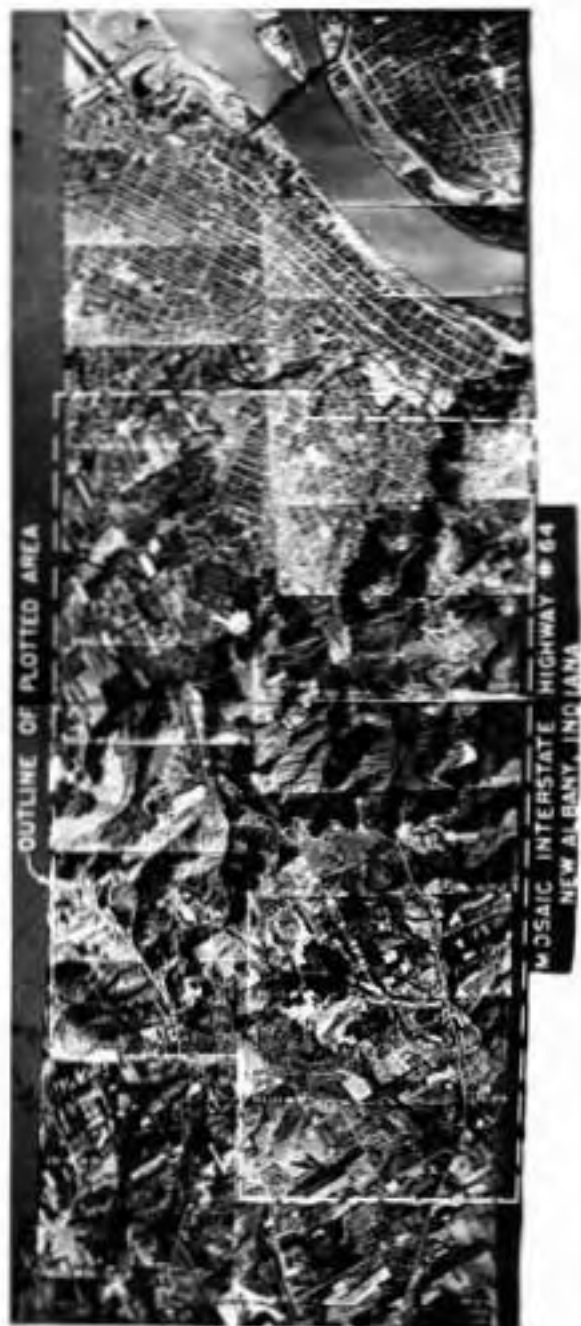


FIG. 5 MOSAIC OF 800 FEET-PER-INCH PHOTOGRAPHY OF  
KNOXSTONE ESCARPMENT, NEW ALBANY, INDIANA

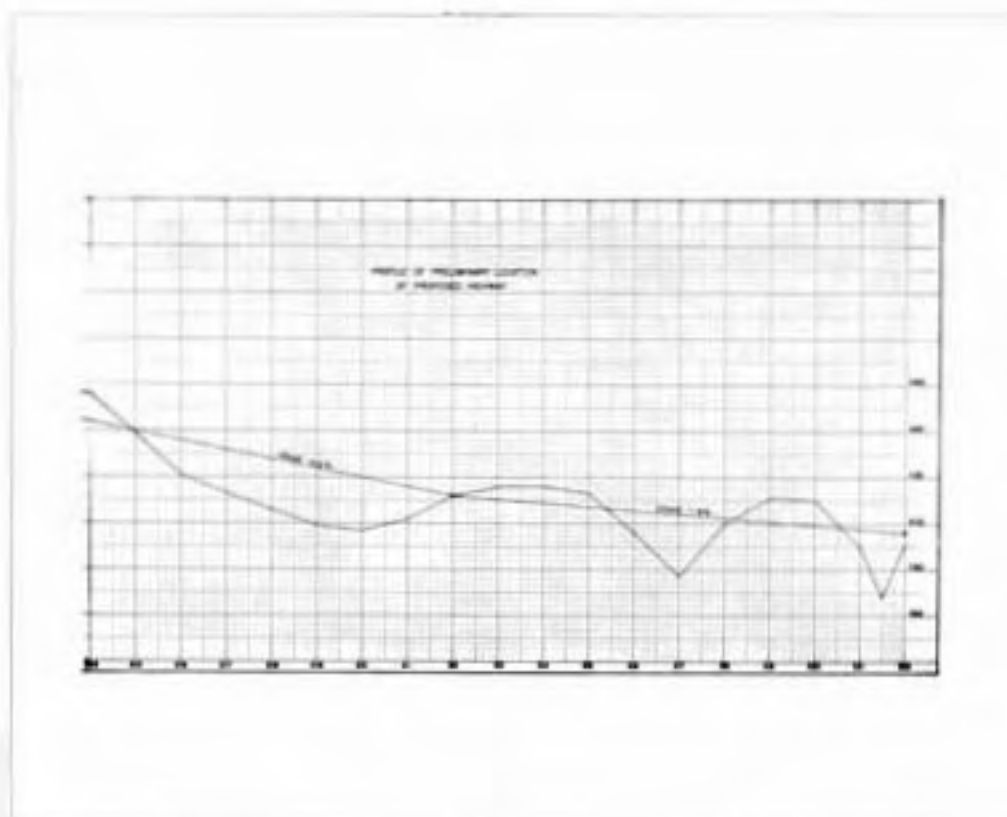


FIG. 6 PRELIMINARY LOCATION CENTER LINE PROFILE  
FROM PHOTOGRAMMETRIC MAP



Transit and tape surveys were conducted to measure 34 lines, or approximately three lines per model at an average length of 1,220 feet each were recorded.

State Plane Coordinate Stations were located for 14 different points in the mapping area.

#### Map Manuscript Assembly

Individual stereo-models were plotted on Kromolite drawing boards (cardboard). There were 13 models plotted, seven in one flight line and six in the other, which had to be assembled into a working drawing. The best means of assembly available was to trace the models onto two rolls of tracing linen. A 1,000 foot grid based on the state plane coordinate grid was ruled on the linen. There were several points on most of the stereo-models with a coordinate designation. These stations were marked on the tracing boards, and the boards were positioned under the linen and traced completely onto the linen as shown in Figure 7. The models were traced first which had the most number of coordinate points and the ones with fewer points next and those lacking any points were traced last and fitted into the rest of the tracing by picture point identification. The finished linens were marked with coordinate grid numbers and any other names such as road names. These linens were then used to make oxlid prints to work on and study of several preliminary location lines.

The use of the coordinates considerably aided the assembly of the adjacent models in the flight lines and aided in controlling the tying of the two flight lines together as well as the establishment of the state plane coordinate grid. There were 15 transit traverse positions of the Geological Survey located in the map area, which were fairly well situated, and which, along with two supplementary points surveyed from traverse



ROLL OF TRACING LINEN MARKED OUT IN STATE PLANE COORDINATE GRID

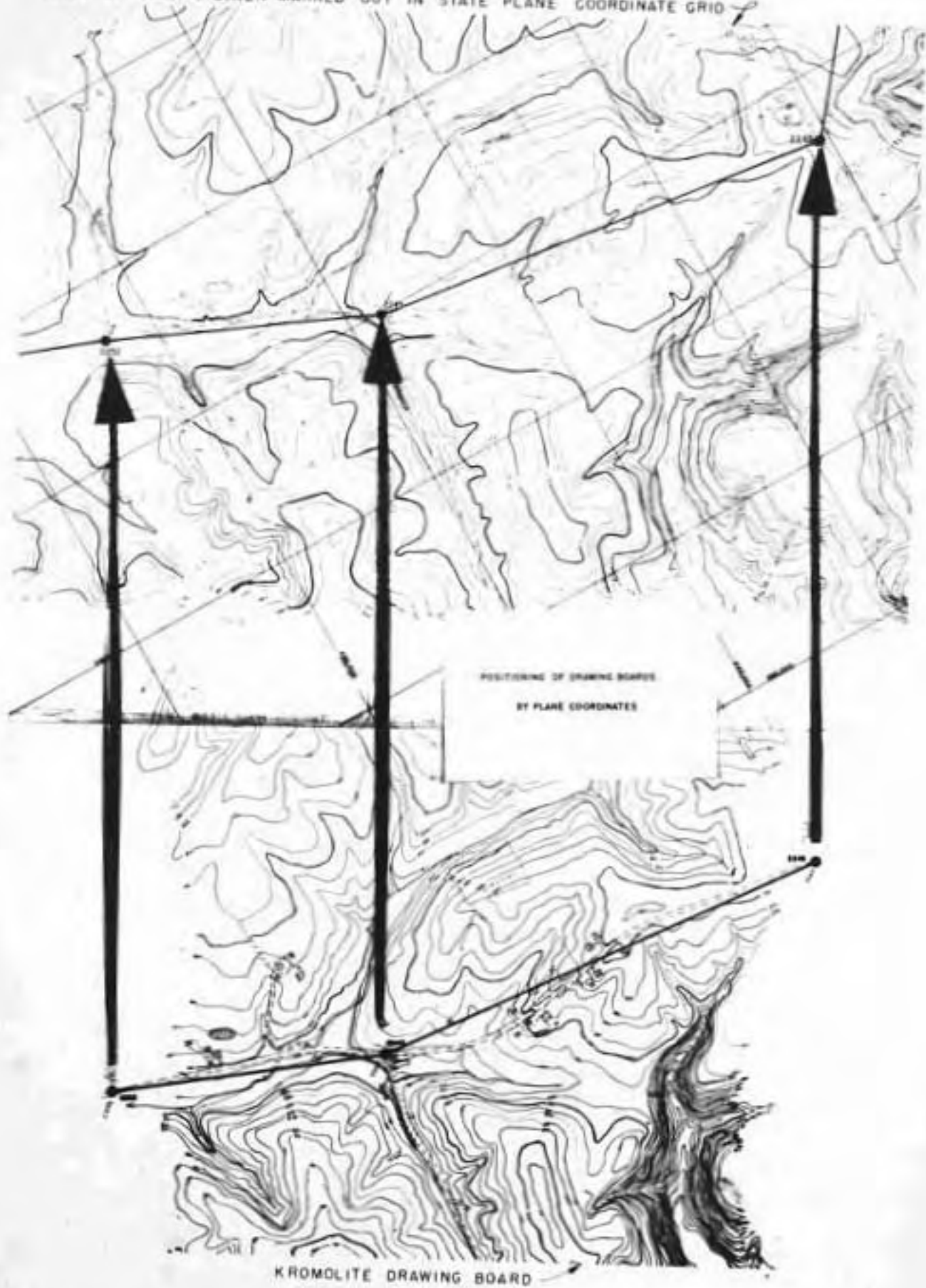


FIG. 7 POSITIONING DRAWING BOARDS FOR TRACING

stations, gave a network of 17 control points which were used to position the models correctly with respect to the state plane coordinate grid.

The locations of the state plane coordinate stations used are shown in Figure 8.

#### ACCURACY CHECK OF THE PHOTOGRAMMETRIC MAP

##### Vertical Accuracy

National standards of map accuracy were used as the criteria for vertical accuracy. The National Standards of Map Accuracy "as applied to contour maps at all publication scales, shall be such that not more than ten percent of all elevations tested shall be in error more than one-half of the contour interval"(4).

A 7,000 foot level test line was surveyed in the field using 20 foot stations. This 7,000 foot profile was then plotted on profile paper with two parallel profiles, one a half contour above the ground profile and the other a half contour interval below the ground profile.

From the plotting boards, the distances were scaled from the origin of the check profile to the point where each contour crossed the center line of the check profile. Distances were also scaled to some ridge and valley lines, and the elevations of these intermediate points were estimated from contour interpolation. Approximately 45 points of known elevation were recorded in this manner and then plotted as spot elevations on the same profile sheet as the true ground profile. A check was made to see if the points tested fell within the half contour band. An analysis of the 45 points tested shows that all the points were within this band.



A summary of points tested showed that:

- 18 points were in error from 0 to 1 foot.
- 8 points were in error from 1 to 2 feet.
- 10 points were in error from 2 to 3 feet.
- 6 points were in error from 3 to 4 feet.
- 3 points were in error from 4 to 5 feet.
- 0 points were in error from 5 or more feet.

#### Horizontal Accuracy

The horizontal accuracy of mapping is usually defined as the allowable difference between the plotted position of a well defined point and its true map position at the plotted map scale.

The National Standards of Map Accuracy specify that 90 percent of all points tested shall not be in error more than 1/30-inch on maps published at scales larger than 1/20,000. Engineering map specifications usually specify 90 percent of all planimetric features shall be within 1/40-inch of their true coordinate position and none shall be in error more than 1/20-inch from their true position (4). For maps at 200 feet-per-inch, as used in this project, the error tolerances for horizontal measurements are:

National Standards of 1/30-inch = 6.6 feet for 90 percent of points tested.

Engineering Map Standards maximum of 1/20-inch = 10 feet.

Engineering Map Standards 1/40-inch = 5 feet.

It was possible in this project to test the horizontal accuracy in two ways: By using the topography references along the 7,000 foot check profile run by the State Highway Department and by the use of U. S. Geological Survey Transit traverse notes.

The profile notes gave distances along the center line of Old Hill Road from its junction with Old Vincennes Road to objects such as building

corners, power poles, and fence corners. It was possible to check the distances along this center line to objects up to about 3,000 feet from the origin. It was not possible to check the remainder of the line as the center line cut across the corners of three plotting boards and the tie to the origin was lost. For the 3,000 feet tested, all the objects plotted were checked with the chained distances. The following list of twelve points gives a comparison between map and taped distances:

Object	Correct Distance (taped)	Map Distance (plotted)	Error (feet)
telephone pole, East side of road	161	157	-4
telephone pole, East side of road	424	420	-4
fence corner post, West side of road	428	425	-3
power pole, West side of road	564	558	-6
fence corner, West side of road	639	632	-7
telephone pole, East side of road	647	640	-7
barn corner, West side of road	759	750	-1
fence corner post, East side of road	1,411	1,403	-8
telephone pole, East side of road	2,200	2,200	0
power pole, West side of road	2,339	2,340	+1
telephone pole, East side of road	2,588	2,585	-3
fence corner post, East side of road	2,875	2,878	+3

The U. S. Geological Survey traverse shown in Figure 8 which traversed the area, when plotted, had nine sides of the traverse which were completely on a single plotting board and, therefore, could be used to check horizontal distances. It was not possible to obtain well defined points for any of these traverse stations, as they were described in such terms as, "center of road intersection," and the interpreted map positions of these stations



could very well be in error by several feet. The errors shown, then, in the following summary do not depend on one plotted position but are the result of two plotted positions. Even though these stations were not well defined positions, it was felt the lines were useful checks because of the long length of the traverse sides with respect to the model size. The horizontal comparison of plotted traverse lengths with true lengths are as follows:

U. S. Geological Survey Traverse Sides Station to Station	Distance (feet)		Error (feet)
	From U.S.G.S. Traverse	From Plotted Map	
2,004 - 2,008	2,158	2,150	- 8
91 - 94	3,792	3,780	-12
94 - 2,003	2,990	2,985	- 5
2,003 - 2,004	2,700	2,690	-10
2,245 - 2,249	2,769	2,775	+ 6
2,249 - 2,252	1,631	1,625	- 6
2,242 - 2,245	1,950	1,940	-10
2,227 - 2,235	1,986	1,990	+ 4

#### Summary.

The vertical accuracy was very good with all points tested being within the allowable error. The horizontal accuracy showed a tendency for the map scale to be a little smaller than true scale. The accuracy test showed several points outside of the allowable margin of error.

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