PHOTOGRAMMETRIC STUDY OF AN AREA PREVIOUSLY MAPPED BY GROUND METHODS

by

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TABLE OF CONTENTS

LIST OF PLATES

INTRODUCTION

Initially, this investigation originated out of the desire of the writer to investigate the fascinating field of photogrammetry as applied to aerial mapping. When the writer's interest was first attracted to the subject, he had had no formal training in it. It was necessary, then, to start with the absorption of basic fundamentals.

Since the first attraction, the writer has had opportunity to teach the subject of photogrammetry as included in advanced surveying courses and has made special effort to increase his knowledge by attending meetings of The American Society of Photogrammetry and to inspect and study some of the establishments and methods of the United States Army, the United States Geological Survey, and the United States Air Force devoted to this field of endeavor. This project has, therefore, along with the teaching and experience just mentioned, served to increase the knowledge of the writer and stimulate his interest in practical and teaching aspects of photogrammetric engineering.

Several aerial mapping agencies and experts in the field of photogrammetry were asked for suggestions or ideas on research and to comment on the writer's intention of making a photogrammetric study of an area previously mapped by ground methods. The reaction of the sources contacted was favorable towards the suggested project, and, from the information furnished by these sources, it seemed fairly certain that no such comparison had been made in a written form. It later came to the attention of the writer that most of the present day developments in photogrammetry are not in the theory which has been well established but in the improvement of the equipment used.

It was, therefore, decided to select an area that had been mapped by ground methods for which there were vertical aerial photographs available and to prepare a map by photogrammetric methods for comparison. Since the writer had been associated with the Central Nebraska Public Power and Irrigation District for three years during the time that project was being surveyed and constructed, this office was contacted and asked to suggest an area in their project for which both topographic maps prepared by ground methods and aerial photographs existed.

The Chief Engineer of the Central Nebraska Public Power and Irrigation District, Mr. George E. Johnson, supplied topographic maps, prepared by ground methods, of an area on the North Platte River, near Ogallala, Nebraska. These maps were prepared in connection with the proposed construction of a large earthen dam, later called the Kingsley Dam. This area was selected because there were Agricultural Adjustment Administration overlapping vertical photographs available for the same area. Some of the section designations of the area involved are Sections 27, 28, 32, 33, and 34 of Township 15 North, and Sections 2, 3, 4, 5, 8, 9, and 10 of Township 14 North, all in Range 38 West of the Sixth Principal Meridian.

The writer is quite familiar with this area as he worked on the Kingsley Dam and reservoir on four different occasions during the early surveys of the area and later during various phases of construction of the dam.

As has been stated, it was the original intention of this investigation to compare a topographic map prepared by photogrammetric methods with a map of the same area compiled from ground surveys. However, lack of sufficient ground control, poor photography, and the uncertainty of the flying height made it difficult to obtain accurate contours even with the more advanced and expensive types of stereo-plotting instruments.

Because of the difficulties just mentioned and the fact that the equipment available would, at best, give merely form lines, only a portion of the contouring was accomplished. A planimetric map of the entire area was obtained to an enlarged scale, however. The approximate flying height, H, of the plane, was obtained by a trial method. The necessary ground control to draw a datum plane correction graph was then secured by approximate methods, and a correction graph was then drawn for a stereoscopic pair of the photographs for which H had been determined. This correction graph was utilized in drawing the contours previously mentioned.

It was anticipated that sufficient ground control could be selected from existing maps in order to complete the photogrammetric map.

REVIEW OF CURRENT LITERATURE

No literature could be found that would bear directly on such a study similar to the one under discussion. However, a number of quotations setting forth the ideas of several authors on the various phases of this investigation are included at relevant places throughout the thesis. A discussion of some of the more important literature on photogrammetry referred to by the writer follows. Additional important literature is listed in the Bibliography.

The Manual of Photogrammetry of the American Society of Photogrammetry, which is often considered the Bible of photogrammetists, consists of seventeen chapters written by various authors and is currently undergoing revision. The portions referred to frequently in this investigation were "Elementary Elevation Determination from Aerial Photographs" by Revere G. Sanders, and "Practical Applications of the Stereocomparagraph" by Albert

L. Nowicki. Pertinent quotations are made from these discussions and included in later pages. Both discussions are part of Chapter XI on "Stereoscopic Mapping Methods".

The writer found Whitmore's presentation on photogrammetry in his recent Advanced Surveying and Mapping of considerable value in clarifying his understanding of the fundamental principles of photogrammetry, and recommends it highly. Mr. Reynold Ask, in his discussion on "Teaching of Basic Photogrammetry" in Chapter XVI of the Manual of Photogrammetry, describes this textbook as an excellent book on elementary photogrammetry.

The United States Army Technical Manual 5-230 on Topographic Drafting was a fruitful source of ideas which helped the author over some of the rough places in this study. This manual is widely considered an excellent text and reference for students in photogrammetry and topographic drafting.

GROUND MAPS AVAILABLE AND METHODS USED

The topographic maps of this area, prepared by the Central Nebraska Public Power and Irrigation District are to a scale of 1" = 200', and are prepared so that each section of land is on a separate sheet. In general, the contour interval is 5 feet. However, this latter varies for some of the sheets. The maps were originally drawn on yellow detail paper and then traced in ink on tracing cloth. The sheets obtained were black and white prints of these tracings. Three of these full size sheets are included as Plates VIII, XV, and XVIII. The remaining sheets were reduced to about 6 by 6 inch size for inclusion in this thesis. All of the topographic maps prepared by both ground and photogrammetric methods are included in the Appendix.

The controlling point method of locating contours was used, utilizing a combination of the plane table and transit-stadia in the field. The plane table was often taken into the field with the transit and the transit-stadia observations reduced and plotted on the spot.

PHOTOGRAPHS AVAILABLE

Two adjacent strips of overlapping Agricultural Adjustment Administration vertical aerial photographs were obtained of this area. One strip consisted of three photographs, and one strip contained four photos. Their relative position has been outlined on the copy of the control sheet on page 12, which is designated Plate I. The identifying marks on the right-hand or eastern strip range from BND 176 158 to BND 176 161, and on the left or western strip, from BND 92 17 to BND 92 19. The identifying markings appear in the upper right-hand corner of each photograph outlined in Plate I.

The Kingsley Dam, in its early stage of construction, appears in the center of the area and in the area of overlap of the two strips. One unusual circumstance is that the two strips were flown about one year apart, the west strip on July 22, 1938, and the east strip on May 5, 1939. This is reflected in the stage of construction of the dam in the two strips. The dam and surrounding area is quite different in the later strip.

The focal length of the camera and the flying height of the plane were not definitely available at the beginning of this problem. In examining the photographs by eye, it was apparent that there was considerable variation in scale in several of the photos. This would indicate a variation in the flying height of the plane.

The abutment of the dam on the south side of the river is much more abrupt than on the north side. The maximum difference in elevation is about 277 feet. There is considerable variation in topography on the south side while the slope of the land on the north side is gradual and the difference in elevation is only about 167 feet. This condition, coupled with very poor photography on the north side, made it impossible to obtain a distinct three-dimensional image of this portion of the terrain under stereoscopic plotting instruments and thus determine when the floating dot was in contact with the surface of the model. The terrain on the south side of the river, while not ideal, was quite suitable for the stereocomparagraph.

GROUND CONTROL AVAILABLE

The existing topographic maps and the plans for the Kingsley Dam and appurtenant structures were the only feasible sources of ground control. Taking points from the ground maps that were to be compared with the photogrammetric map was not especially desirable or accurate. Measurements made on the black and white prints were not only subject to field errors but to plotting errors and the shrinkage and expansion of the drawing paper and of the prints themselves. Since the photogrammetric map was to be compared with the existing maps, it would seem desirable to obtain measurements from some other source. The distance to the site and the extent of the area made a ground survey to obtain properly located ground control prohibitive. Finally, several points along the center line of the dam which appeared on the photos as a line of interlocking sheet-steel piling and on top of the completed stilling basin wall were selected. These points appeared in the area of overlap of the two strips. This did not provide either properly located points or the proper number of points required for accurate mapping. There should be at least three ground control points in the first photograph of each strip with at least two of these being in the area of overlap of the first two photos. Davis and Foote surveying text,[1] and the Army

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[1] Raymond E. Davis and Francis S. Foote, Surveying. New York: McGraw-Hill Book Co., 1940.

Technical Manual 5-230[1] both specify that there should be a minimum of three ground control points in the area of overlap. At least one ground control point should be available at or near the principal point of the last photograph of each strip.

SELECTING SECONDARY OR PHOTOGRAPHIC CONTROL

Eight or more additional well defined points were selected and properly marked on each photograph. An attempt was made to select them as indicated in the sketch below.

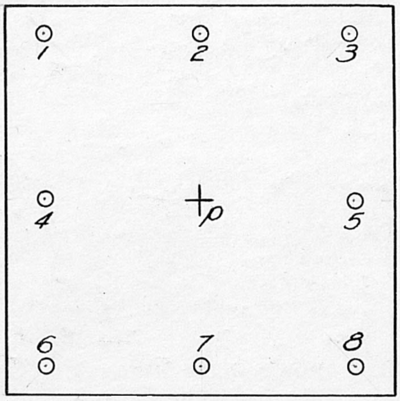

Fig. 1

The actual location of these points varied somewhat from the above and was governed by the points available and the necessity of obtaining the points in the areas of overlap. Five points were selected on each overlapping pair that could be easily distinguished on each photo. Also, the points on the sides of the photos that were adjacent to the adjoining strip had to be selected so that they were in the area of overlap of the two strips and plainly visible on the adjacent photos. These secondary control points are also referred to as "wing points" and serve as "tie points" when they are used to tie adjacent flights or strips together.

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[1] Topographic Drafting. United States Army Technical Manual 5-230. Washington: Government Printing Office, 1940.

PLOTTING CONTROL

The radial line method was employed to plot the photographic control points. The project was not of sufficient extent to use the mechanical triangulators. The photographs were oriented, one at a time, underneath the transparent control sheet and the rays from the center points to the various ground and photographic control points were traced.

Since there was not sufficient ground control as pointed out in previous discussion, a method described in Army Technical Manual 5-230, on page 193, was utilized. It is called "plotting to scale of first two photographs," and is usual military procedure since there is seldom ideal distribution of ground control when maps are made of new terrain.[1]

Since there was some doubt about the accuracy obtained in transferring principal points to adjacent photographs, substitute centers were selected near each principal point. Objects or ground features that could be positively identified were selected for this purpose. Army Technical Manual 5-230 states that such substitute centers should be "well-defined detail as near the principal point as possible, preferably not more than 0.2 inch away normal to the line of flight, and not over 0.4 inch away along the line. It is assumed that within these limits the course line, as drawn on the photograph, will be so close to its true direction as not to introduce any error into the azimuth plotting."[2]

Since the centerline of the dam and its structures were plainly visible on the photographs and stationing and elevations were readily obtained from the available plans, three ground control points were selected along the dam.

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[1] Op. cit.

[2] Op. cit.

The dam itself is conveniently located in the area of overlap of the two strips of photos and portions of it appear in all of the photographs. Thus the centerline of the dam is the backbone of the map. The three ground control points are Δ A on the stilling basin wall, Δ B at the intersection of the dam centerline with the railroad centerline on the north abutment, and Δ C at the north end of the sheet-steel piling. This last point did not seem to line up very well when the planimetry was applied to the control sheet by means of the rectoplanigraph and was, therefore, abandoned.

The above ground control points and all photographic control points appear on a copy of the original control sheet, or Plate I, and the copy of the final planimetric map, or Plate II.

"Plotting to the scale of the first two photographs" is accomplished by using the mean of the distances between the substitute centers of the first two photographs in a strip.[1] In this case, photos BND 176 158 and BND 176 159 are used. Photo 158 was first placed underneath the transparent control sheet, the substitute centers 158-C and 159-C were traced, and then the outer ends of the radial lines to all control points were drawn. The mean of the distances between the substitute centers 158-C and 159-C was determined by scaling from the two photos, and the plotted distance between the two points was adjusted to equal the mean distance. By placing the photo 159 with substitute center 159-C below the adjusted point on the control sheet and rotating until the line from 159-C to 158-C on the photo corresponded with the same line on the control sheet, the second photograph was oriented. Rays to all of the control points on photograph 159 were traced and where these new rays intersected the previous rays of photo 158, the intersection was the location of the control points to which the radial

[1] *Op. cit.*

rays were drawn on the two photos. The control points were then properly located to the mean scale of the first two photos.

The control points common to photographs 160 and 159 were located by first placing photograph 160 beneath the control sheet and making the rays between the substitute center points 159-C and 160-C on the photo and the control sheet correspond, as with previous photos, and moving photograph 160 maintaining this agreement until rays through ground control point ΔA, 159-R, and 159-L_2 on photo 160 intersected the corresponding points previously located on the control sheet. Rays to all control points on photo 160 were then traced on the control sheet. Where intersection with rays to corresponding points on photo 159 occurred, these intersections defined the location of the same control points common to photos 159 and 160 not previously located. The control points in the end photo of the strip were located in the same manner. At this stage in the plotting, all ground and photographic control points of the four photos in the east strip were located to the mean scale of the first two photos.

A difference here from the usual methods of plotting control is that the ground control points were located by intersection of rays the same as the photographic control points. Usually, where there are sufficient ground control points, the ground control is plotted on the control sheet to a desired scale and the radial line plotting is adjusted to these points.

In order to tie in the west strip of photos, the center photo of the strip, photo BND 92 18, was first placed beneath the control sheet so that radial lines from the substitute center point 18-C through tie points 160-L, 159-L_1, 159-L_2, 158-L, and ground control points A and B passed through these same points previously plotted in the adjacent strip. The substitute center point of the photo could then be located on the control

EXPLANATION OF PLATE I

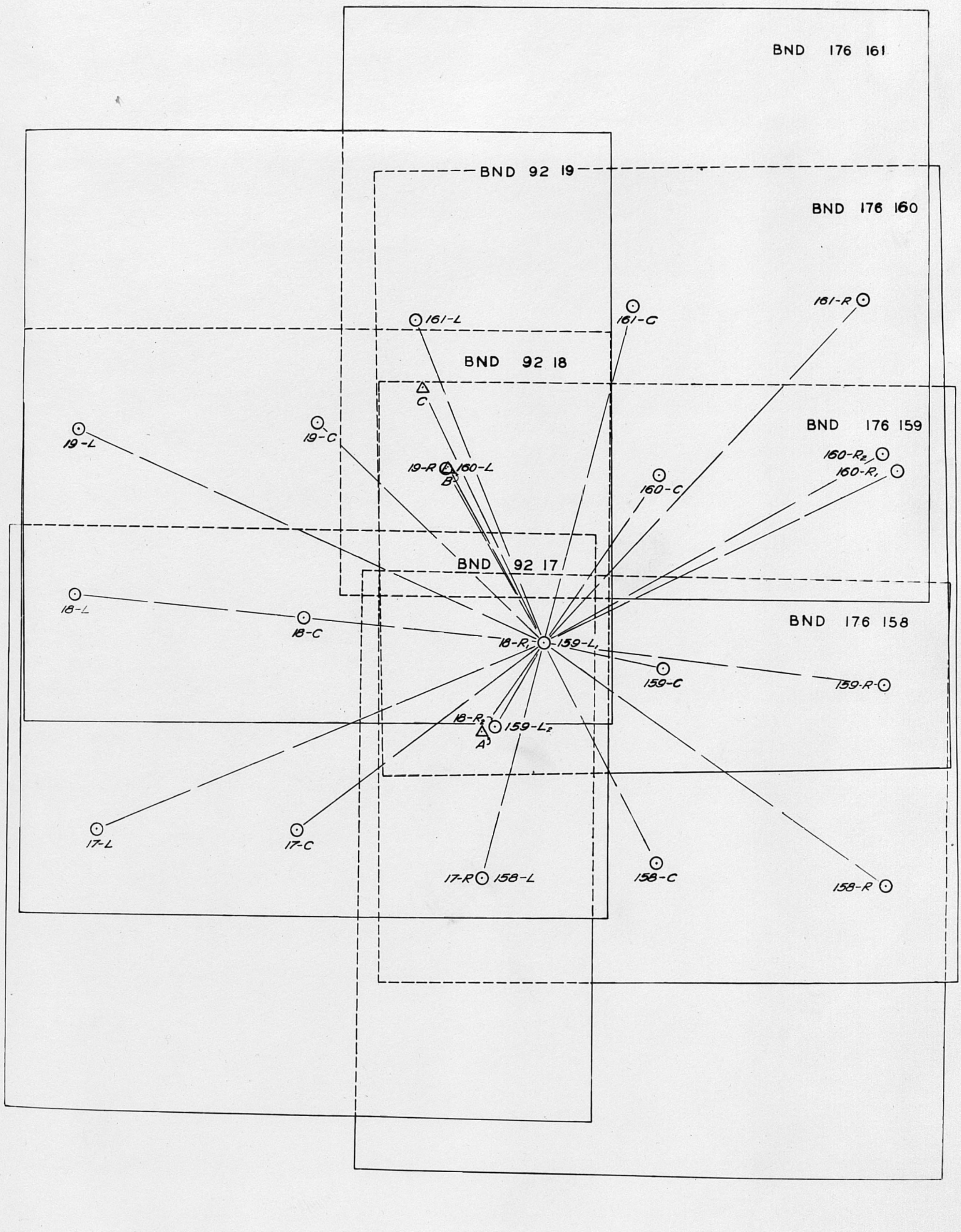
Control sheet and index to photographs

Note: Radiating lines from secondary control point 159-L_1 or 18-R_1 are those used for enlarging the scale as described on page 13.

Legend: △ Ground Control Points.

⊙ Photographic Control Points.

PLATE I


BND 176 161
BND 92 19
BND 176 160
161-R
161-L
161-C
BND 92 18
C
BND 176 159
19-L
19-C
19-R
160-L
B
160-R2
160-R1
160-C
BND 92 17
18-L
18-C
18-R1
159-L1
BND 176 158
159-C
159-R
18-R2
159-L2
A
17-L
17-C
17-R
158-L
158-C
158-R

sheet and radial lines to the remaining photographic control points on this photograph were drawn.

Photographs BND 92 17 and BND 92 19 could then both be tied in to their common tie points on the adjacent strip and the substitute center point 18-C. Radial lines intersecting the rays previously drawn from substitute center point 18-C defined the position of the common control points on the control sheet and all control points were then plotted to the mean scale of the first two photos in the eastern strip.

To increase the scale of the map, a method was devised for increasing the plotted scale of the control one and one-half times. Radiating lines were drawn from centrally located point 159-L_1 or 18-R_1 through the remaining control points. This system of radiating lines was then transferred to a larger sheet of tracing paper maintaining the exact angular values between the lines. The distances from the central point 159-L_1 to the outer control points were measured with a pair of dividers and laid off on the new sheet along the radial lines. Each distance was then increased by one-half along these radial lines and the new positions of the control points were plotted. Special care was exercised in transferring the radial lines and distances to the new control sheet. The control was then plotted to a scale one and one-half times the mean scale of the first two photos and the new control sheet was ready to receive the planimetry.

PLOTTING PLANIMETRY

When the scale of the control sheet was enlarged, it was planned to utilize the rectoplanigraph in transferring planimetry from the photographs to the control sheet. Blowing up the scale one and one-half times provided a worthwhile application of the rectoplanigraph which is capable of a

EXPLANATION OF PLATE II

Planimetric map

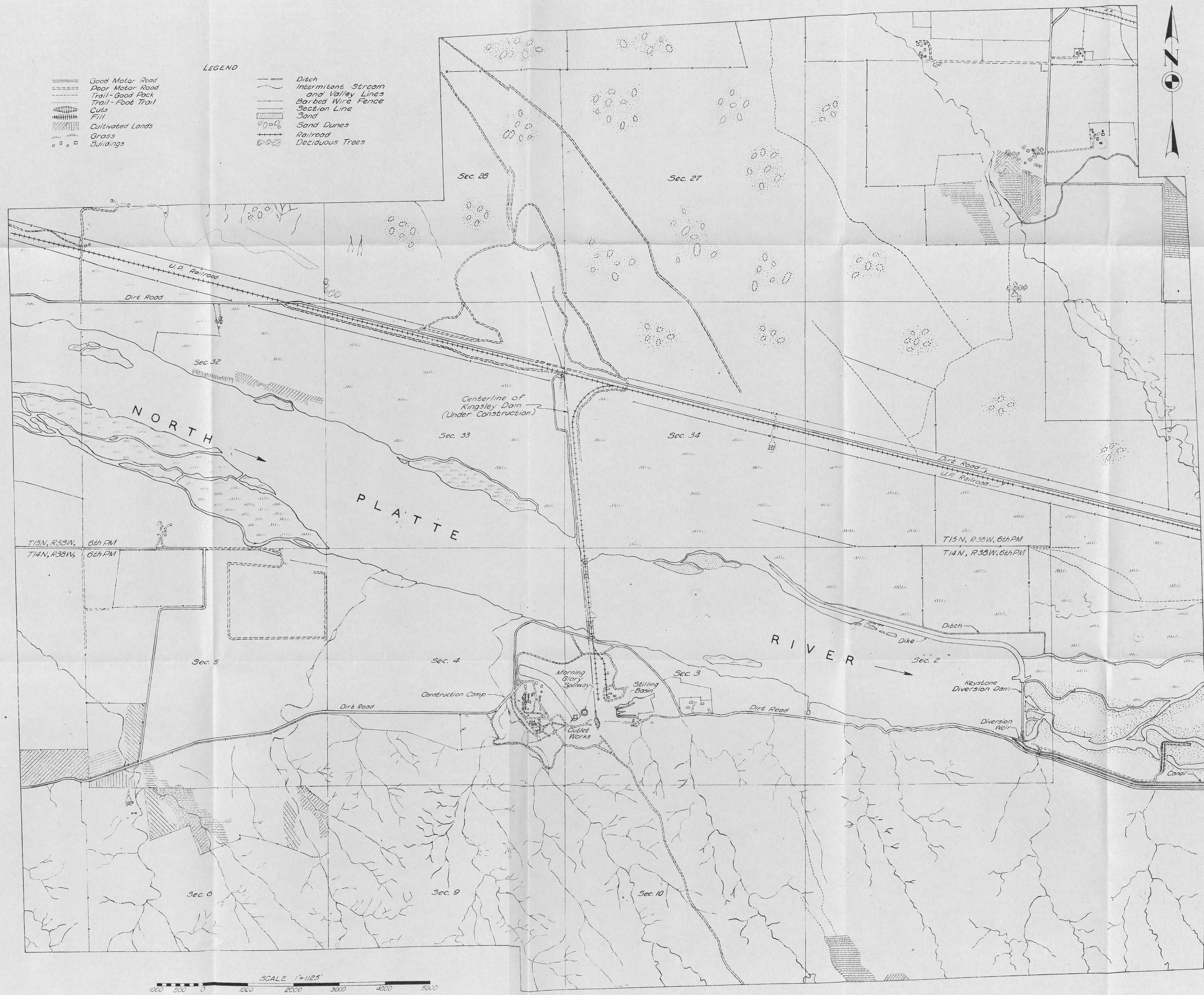
Planimetric map prepared by photogrammetric methods. Area is in vicinity of Kingsley Dam of the Central Nebraska Public Power and Irrigation District near Ogallala, Nebraska.

Section numbers are indicated so that the maps prepared by ground methods, appearing in Plates IV, VI, and VIII to XVIII, can be located and compared. Section lines appear only in their approximate locations.

PLATE II

Planimetric map

PLATE II


LEGEND
Good Motor Road
Poor Motor Road
Trail - Good Pack
Trail - Foot Trail
Cuts
Fill
Cultivated Lands
Grass
Buildings
Ditch
Intermitant Stream and Valley Lines
Barbed Wire Fence
Section Line
Sand
Sand Dunes
Railroad
Deciduous Trees
N
Sec. 28
Sec. 27
U.P. Railroad
Dirt Road
Sec. 32
NORTH
PLATTE
RIVER
Centerline of Kingsley Dam (Under Construction)
Sec. 33
Sec. 34
Dirt Road
U.P. Railroad
T15N, R38W, 6th PM
T14N, R38W, 6th PM
T15N, R38W, 6th PM
T14N, R38W, 6th PM
Ditch
Dike
Sec. 5
Sec. 4
Morning Glory Spillway
Stilling Basin
Sec. 3
Sec. 2
Keystone Diversion Dam
Construction Camp
Dirt Road
Dirt Road
Outlet Works
Diversion Weir
Canal
Sec. 8
Sec. 9
Sec. 10
SCALE 1"=1125'
1000 500 0 1000 2000 3000 4000 5000

magnification of two and one-half. Also, it was intended to obtain a map of larger scale which could be a little more reasonably compared with the original ground maps of a still much larger scale.

Each one of the seven photos was placed in the picture holder of the rectoplanigraph separately. The picture holder was then moved vertically on a vertical column to obtain the magnification in scale and tilted to correct for tip and tilt. When the image of the control points on the photo in the picture holder was made to agree with the same plotted control points on the control sheet underneath the rectoplanigraph, the planimetry in the area of overlap was traced by following the image lines plainly visible on the control sheet.

Actually there was considerable variation of the scale on the several photographs and the magnification required for each photo varied. There was considerable variation in scale between the photos of the two strips. This is not surprising since they were flown about nine months apart.

DETERMINATION OF FLYING HEIGHT

The following method of determining an unknown flying height is extracted from notes furnished students in photogrammetry at Pennsylvania State College and was supplied the writer by Professor Lawrence J. Perez, Professor of Photogrammetry at that school. According to Professor Perez's belief, Professor Earl Church, Professor of Photogrammetry at Syracuse University, Syracuse, New York, is given credit for developing this method.

The flying height must be known in order to calculate elevation changes on the ground. A simple relationship for vertical aerial photographs is $\frac{f}{H} = \frac{d}{D}$, from which H, the flying height, equals $\frac{fD}{d}$, where D is the distance, in feet, between two points on the ground, and "d" is the distance, in inches, between the same two points on the photo. However, "d" on the photo is affected by "relief displacement", so an adjustment must be made to correct this condition.

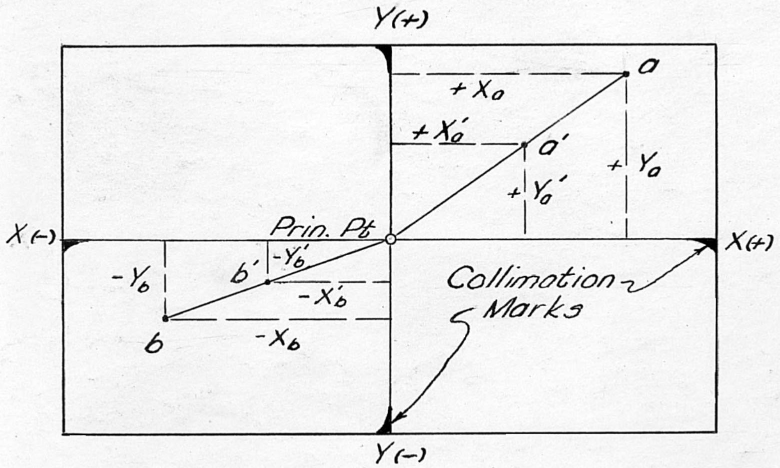
In order to compute this flying height from a single aerial photograph, the following information must be known:

a. Difference in elevation and horizontal distance between two ground points, identifiable on photo.

b. Focal length of camera.

The calculations necessary to determine the flying height are shown in the following example:

a. As in Figure 2, measure the co-ordinates X_a, X_b, Y_a, Y_b, of the images on the photos of the two ground control points, paying attention to plus and minus signs. Use the lines connecting the collimation points as the axes of the co-ordinates.



Points "a" and "b" are the photo image points of "A" and "B" on ground. "a'" and "b'" would be the positions of these two points had they been at 0 datum. aa' and bb' represent the respective displacements produced by relief of these two points.

Fig. 2

b. Compute the photographic distance ab, in inches, between the two control points. ab, being the hypotenuse of a right triangle, is computed from the expression

$$ab = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2} = \text{Equation 1.}$$

Check this distance by direct measurement of ab on the photo.

c. Determine an approximate value for the flying height so as to compute the datum or map co-ordinates of the ground points.

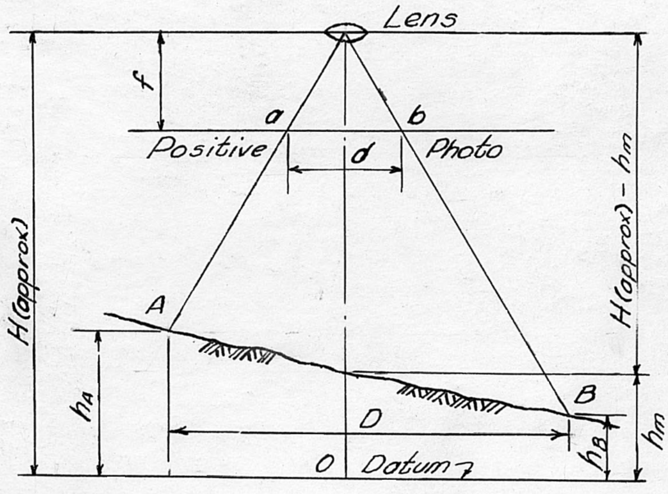


Fig. 3.

In Fig. 3, $\frac{H_{(approx)} - h_m}{f} = \frac{D}{d} =$ Scale (approx) from which $H_{(approx)} = \frac{fD}{d} + h_m$ (Eq. 2). In this equation, "D" is the horizontal ground distance, in feet, between points A and B.

"d" is the photo distance, in inches, between images of A and B, ((ab) on photo).

"h_m" is the mean elevation of A and B.

d. Compute the co-ordinates of the datum position of the ground points. This computation eliminates the effect of displacement of image due to relief, by reduction of all points to a common datum.

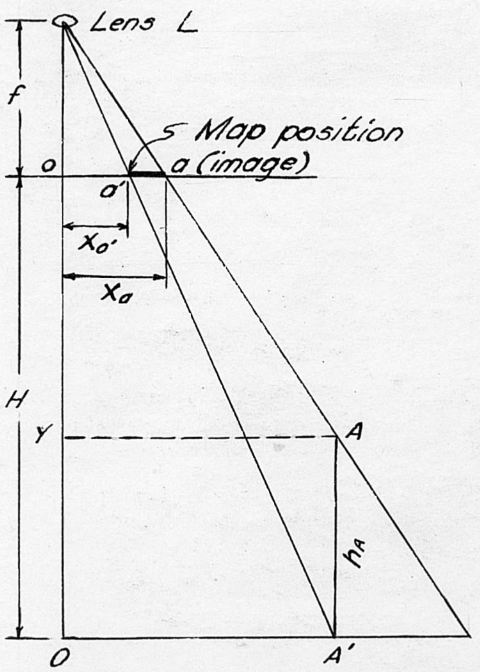


Fig. 4.

From Fig. 4, using Δ oLa and Δ YLA

$$\frac{X_a}{AY} = \frac{f}{H-h_A} \text{ ; and in } \Delta\, oLa' \text{ and } \Delta\, OLA'$$

$$\frac{X_a'}{OA'} = \frac{f}{H} \text{ ; since } AY = OA', \text{ then}$$

$$X_a' = X_a\frac{(H-h_A)}{H} \text{ . Similarly,}$$

$$X_b' = X_b\frac{(H-h_B)}{H} \text{ ; } Y_a' = Y_a\frac{(H-h_A)}{H} \text{ ;}$$

$$Y_b' = Y_b\frac{(H-h_B)}{H} \text{ .}$$

It should be understood that X_a' is the "X" component of radial distance from the principal point to the map or datum position of point a, or where A would have appeared in the photo had it been on the datum plane.

e. Compute the photographic distance, d', (reduced to sea level), between the ground control points. d' = a'b' in Fig. 2.

$$d' = \sqrt{(X_a' - X_b')^2 + (Y_a' - Y_b')^2} \quad \text{(Eq. 3).}$$

Note that this computed distance, d', would be the photo distance between points A and B had these points been at 0 datum.

f. The corrected value of the flying height is then obtained from the expression

$$H = f \frac{D}{d'} \quad \text{(Eq. 4)}.$$

Investigate to see that this value of H does not appreciably change the co-ordinates X_a', X_b', Y_a', Y_b', which were calculated from the approximate value of H.[1]

Example:

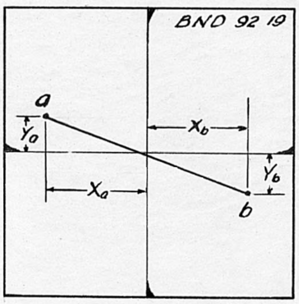


Fig. 5.

$D = 10{,}719'$; $h_a = 3{,}147'$; $h_b = 3{,}141'$; $f = 8.25''$.

$X_a = -3.70''$ $\quad Y_a = +0.26''$

$X_b = +2.14''$ $\quad Y_b = -0.68''$

$d = \sqrt{(\overline{5.84})^2 + (\overline{0.94})^2} = 5.915''$ (from Eq. 1).

d (measured) = 5.91" which checks.

$H_{(approx)} = \frac{8.25 \times 10{,}719}{5{,}915} + 3{,}144 = 18{,}094$ (from Eq. 2).

From the derivation accompanying Figure 3, the 0 datum coordinates of a and b are: $X_a' = X_a \cdot \frac{H-h_a}{H} = -3.70(1 - \frac{3{,}147}{18{,}094}) = 3.06''$. Similarly, $X_b' = 1.77''$; $Y_a' = 0.215''$; $Y_b' = 0.562''$.

From Equation 3, $d' = \sqrt{(\overline{4.83})^2 + (\overline{0.777})^2} = 4.892''$. From Equation 4, $H = \frac{8.25 \times 10{,}719}{4.892} = 18{,}077'$.

This value of H, if now used to determine $X_a' = X_a \frac{H-h_a}{H}$ above, would cause no appreciable change in X_a' value: therefore, there is no need to recalculate X_a', Y_a', and Y_b', by this method of repeated calculations.

A number of trials for the value of H were made in the three photos BND 92 17, BND 92 18 and BND 92 19 of the west strip. The topographic sheets were matched and taped together to form one large map. Points were selected

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[1] Determination of Flying Height. Department of Civil Engineering, The Pennsylvania State College, State College, Pennsylvania.

on the photographs that could be identified on the maps and for which the ground elevations were indicated or easily interpolated from adjacent contours.

The ground distance D between any two points was obtained by scaling directly with a Lufkin steel tape from the large map which was laid flat on the floor. Values of d and X and Y co-ordinates were scaled from the photographs with an engineer's scale. The results of these trials are tabulated as follows.

Table 1. Determination of flying height. Data used and results obtained.

Photo	D (ft)	X_a (in)	X_b (in)	Y_a (in)	Y_b (in)	d (in)	H(ft) (approx)	X_a' (in)	X_b' (in)	Y_a' (in)	Y_b' (in)	d' (in)	H (ft)
BND 92 17	14,000	-3.58	+4.05	+0.59	-0.54	7.71	18,255	+2.94	-3.32	+0.49	-0.44	6.34	18,236
BND 92 17	11,433	-2.56	+3.32	-1.24	+0.83	6.23	18,383	-2.11	+2.73	-1.02	+0.67	5.12	18,412
BND 92 18	13,906	-2.77	+2.51	+3.62	-2.03	7.73	18,037	-2.27	+2.07	+2.97	-1.68	6.36	18,036
BND 92 18	13,100	-1.67	+1.08	+3.28	-3.70	7.50	17,591	-1.37	+0.88	+2.69	-3.02	6.14	17,610
BND 92 19	10,719	-3.70	+2.14	+0.26	-0.68	5.92	18,094	-3.06	+1.77	+0.22	-0.56	4.89	18,077
Average													18,074

The points a and b for each trial were selected on opposite sides of the principal point so that a line connecting them crossed or came very near the principal point. Two different points were used for each trial. The variation between the values of H obtained for the same photograph is attributed chiefly to the method of obtaining the ground distance D. In scaling the distance from the map, errors would be introduced due to errors in plotting, matching of the prints, and shrinkage or expansion of the prints.

ELEVATION STUDIES

Accuracy of Stereocomparagraph

The stereocomparagraph, one of the simplest forms of stereoscopic equipment used for elevation determination, was the only type of such equipment available. "Under optimum conditions with a reasonably expert operator and with good control available," only form lines (not contours) can be obtained. On page 451 of the Manual of Photogrammetry, Mr. Revere G. Sanders states that, under the conditions mentioned above, "spot elevations can be determined with simple stereoscopic equipment to an order of accuracy of ± 1/400th or ± 1/500th of the flight altitude" and that the possible accuracy of sketching form lines "under the best conditions falls off to approximately ± 1/250th of the flying altitude."[1]

Datum Plane Correction Graph

A refinement in preparing contour maps with the stereocomparagraph or

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[1] Revere G. Sanders, "Elementary Elevation Determination from Aerial Photographs," Manual of Photogrammetry, p. 451.

similar equipment is the use of the datum plane correction graph. "By its use compensations are made for distortions due to tip or tilt, irregular shrinkage of negatives and prints, variations in flight altitude, vacuum plate failure, lens distortion, and also distortions arising from errors existing in the present widely used Parallax Tables. The accuracy of the final contoured templet sheet depends, to a great extent, on the care with which the correction graph is constructed."[1]

The correction graph appearing in Plate III is for photo BND 92 18 to be used for the area of overlap of that photograph and photo BND 92 17. In preparing the correction graph, a value of H = 18,074 feet was used, which is the average of the H values appearing in Table 1 for the three photos of the western strip. The stereoscopic base was determined approximately by measuring the distance between plumb point and transferred plumb point by both photographs, and averaging the two values as follows:

B_m of Photo 17 = 80.0

B_m of Photo 18 = $\underline{80.8}$

Average B_m = 80.4 mm

Twenty-six prominent points were selected in the area of overlap as vertical control points for the correction graph. These points were readily identified in both the area of overlap of the two photographs and on the ground maps. The elevations of all of these points were obtained from the ground maps except for the elevation of ground control point Δ A which was obtained from separate plans for that structure.

A micrometer reading "form sheet" was compiled for the two photos being studied, and is reproduced as Table 2. The elevations of the vertical

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[1]Albert L. Nowicki, "Practical Applications of Stereocomparagraph," _Manual of Photogrammetry_, p. 474.

control points are recorded in column (4), while the micrometer readings made with the stereocomparagraph for each point appear in column (6). The Δp in column (2) were interpolated for the corresponding (H-h) values from the Master Parallax Tables. Δph in column (3), then, would be for $B_m = 100$ mm. The values of Δph for the stereo pair concerned are derived by multiplying the values of Δph in column (3) by $B_m/100$ and are entered in column (5). The difference between $\frac{\Delta ph \times B_m}{100}$ in column (5) and the micrometer reading in column (6) is the correction to be applied to the micrometer reading and is entered in column (7).

A transparent sheet was then placed over the left-hand photograph and the positions of the vertical control points traced. The control points were then marked with their corresponding values found in column (7). Interpolation was made between adjacent control points for 0.05 mm intervals and the graph lines were then sketched in connecting interpolated points of equal value. A copy of the completed correction graph appears as Plate III.

The *Manual of Photogrammetry* specifies that when the Master Parallax Tables are used in compiling the data for the correction graph, a much greater number of points is necessary than would be needed if the formula $p = B_m \frac{h}{(H-h)}$ is used, especially in rugged country. For accurate results, control points would have to be located at all critical breaks in the topography.[1]

As previously mentioned, the accuracy of the correction graph is mainly dependent upon the number of vertical control points used. However, for the stereoscopic pair of photos BND 92 17 and BND 92 18, a good share of the area used is very rugged and it would be quite difficult, if not impossible,

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[1] *Ibid.*

to locate all of the critical breaks in slope. Also, since the elevations were picked off of the ground map, the selection of control points was governed by those points which could be identified on both photos and maps.

In preparing the micrometer reading form sheet, appearing as Table 2, the values of $B_m = 80.4$ mm and $H = 18{,}074$ feet, previously mentioned, have been used.

Table 2. Values of micrometer readings for corresponding elevations appearing on left hand photo BND 92 18.

1	2	3	4	5	6	7
H-h	$\Sigma\Delta p$	Δph	h	$\frac{\Delta phxB_m}{100}$	Micrometer reading	Micrometer reading to sea level
Micrometer readings for correction graph vertical control points						
18,074	32.440					
14,949	51.423	18.983	3125	15.26	10.98	4.28
14,946	51.443	19.003	3128	15.28	11.25	4.03
14,944	51.456	19.016	3130	15.29	10.87	4.42
14,940	51.483	19.043	3134	15.31	11.67	3.64
14,936	51.510	19.070	3138	15.33	11.67	3.66
14,920	51.617	19.177	3154	15.42	10.93	4.49
14,915	51.650	19.210	3159	15.45	11.26	4.19
14,914	51.657	19.217	3159.6	15.45	12.45	3.00
14,911	51.677	19.237	3163	15.47	12.31	3.16
14,901	51.744	19.304	3173.2	15.52	11.24	4.28
14,886	51.845	19.405	3188	15.60	11.88	3.72
14,865	51.986	19.546	3209	15.71	11.13	4.58
14,853	52.067	19.627	3221	15.78	12.69	3.09
14,840	52.155	19.715	3234	15.85	11.24	4.61
14,824	52.263	19.823	3250	15.94	12.91	3.03
14,822	52.277	19.837	3252	15.95	12.83	3.12
14,804	52.398	19.958	3270	16.05	12.22	3.83
14,800	52.425	19.985	3274	16.07	12.50	3.57
14,799	52.432	19.992	3275	16.07	11.01	4.26
14,789	52.499	20.059	3285	16.13	11.63	4.50
14,769	52.634	20.194	3305	16.24	11.43	4.81
14,766	52.655	20.215	3308	16.25	11.35	4.90
14,853	52.067	19.627	3220.9	15.78	11.46	4.32
14,737	52.851	20.411	3337	16.41	11.57	4.84
14,669	53.314	20.874	3405	16.78	12.75	4.03
Micrometer readings for contours						
18,074	32.440		0			
14,934	51.523	19.083	3140	15.34		
14,914	51.657	19.217	3160	15.45		
14,894	51.791	19.351	3180	15.56		
14,874	51.926	19.486	3200	15.67		
14,854	52.061	19.621	3220	15.78		
14,814	52.331	19.891	3260	15.99		
14,774	52.601	20.161	3300	16.21		
14,734	52.872	20.432	3340	16.43		
14,694	53.144	20.704	3380	16.65		
14,674	53.280	20.840	3400	16.76		

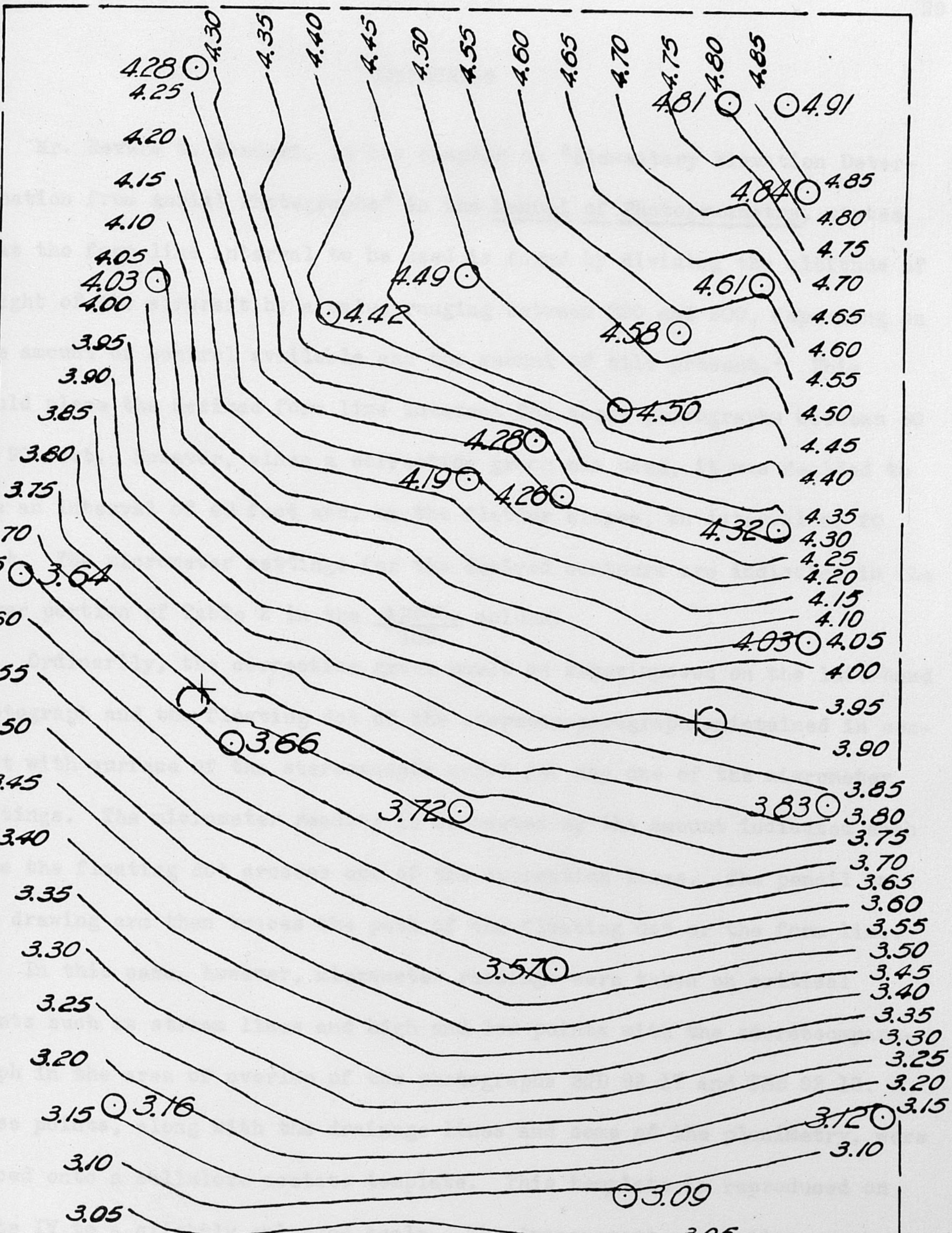
EXPLANATION OF PLATE III

Datum plane correction graph

Datum plane correction graph for photograph BND 72 18 and used for area of overlap of photographs BND 72 18 and BND 72 17.

The correction values are read from the graph in millimeters.

PLATE III


4.30
4.35
4.40
4.45
4.50
4.55
4.60
4.65
4.70
4.75
4.80
4.85
4.28
4.25
4.81
4.91
4.20
4.15
4.84
4.85
4.10
4.80
4.75
4.05
4.03
4.49
4.61
4.70
4.00
4.42
4.65
4.58
3.95
4.60
3.90
4.55
3.85
4.50
4.50
4.28
4.45
3.80
4.19
4.26
4.40
3.75
4.35
3.70
4.32
4.30
4.25
3.65
3.64
4.20
4.15
3.60
4.10
4.03
4.05
3.55
4.00
3.95
3.50
3.66
3.90
3.45
3.85
3.72
3.83
3.80
3.40
3.75
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3.16
3.12
3.15
3.10
3.10
3.09
3.05
3.05
3.00
3.03

CONTOURING

Mr. Revere G. Sanders, in his chapter on "Elementary Elevation Determination from Aerial Photographs" in the Manual of Photogrammetry, states that the form line interval to be used is found by dividing the altitude of flight of the aircraft by a value ranging between 200 and 300, depending on the amount of control available and the amount of tilt present.[1] This would place the desired form line interval for these photographs between 60 to 90 feet. However, since a correction graph was used, it was decided to use an interval of 40 feet and, on the flatter slopes, an interval of 20 feet. The micrometer settings for the desired contours are indicated in the lower portion of Table 2 in the $\frac{\Delta phxB_m}{100}$ column.

Ordinarily, the correction graph would be superimposed on the left-hand photograph and the floating dot of the stereocomparagraph maintained in contact with surface of the stereoscopic model for any one of the micrometer settings. The micrometer reading is corrected by the amount indicated each time the floating dot crosses one of the correction lines. The pencil on the drawing arm then traces the path of the floating dot or the form line.

In this case, however, micrometer readings were taken on critical points such as stream lines and high and low points with the stereocomparagraph in the area of overlap of the photographs BND 92 17 and BND 92 18. These points, along with the drainage lines and some of the planimetry, were traced onto a cellulose acetate template. This template is reproduced on Plate IV to a slightly enlarged scale. The transparent correction graph, also on cellulose acetate, was placed over the template and the proper correction could then be picked off for the points desired. These corrections

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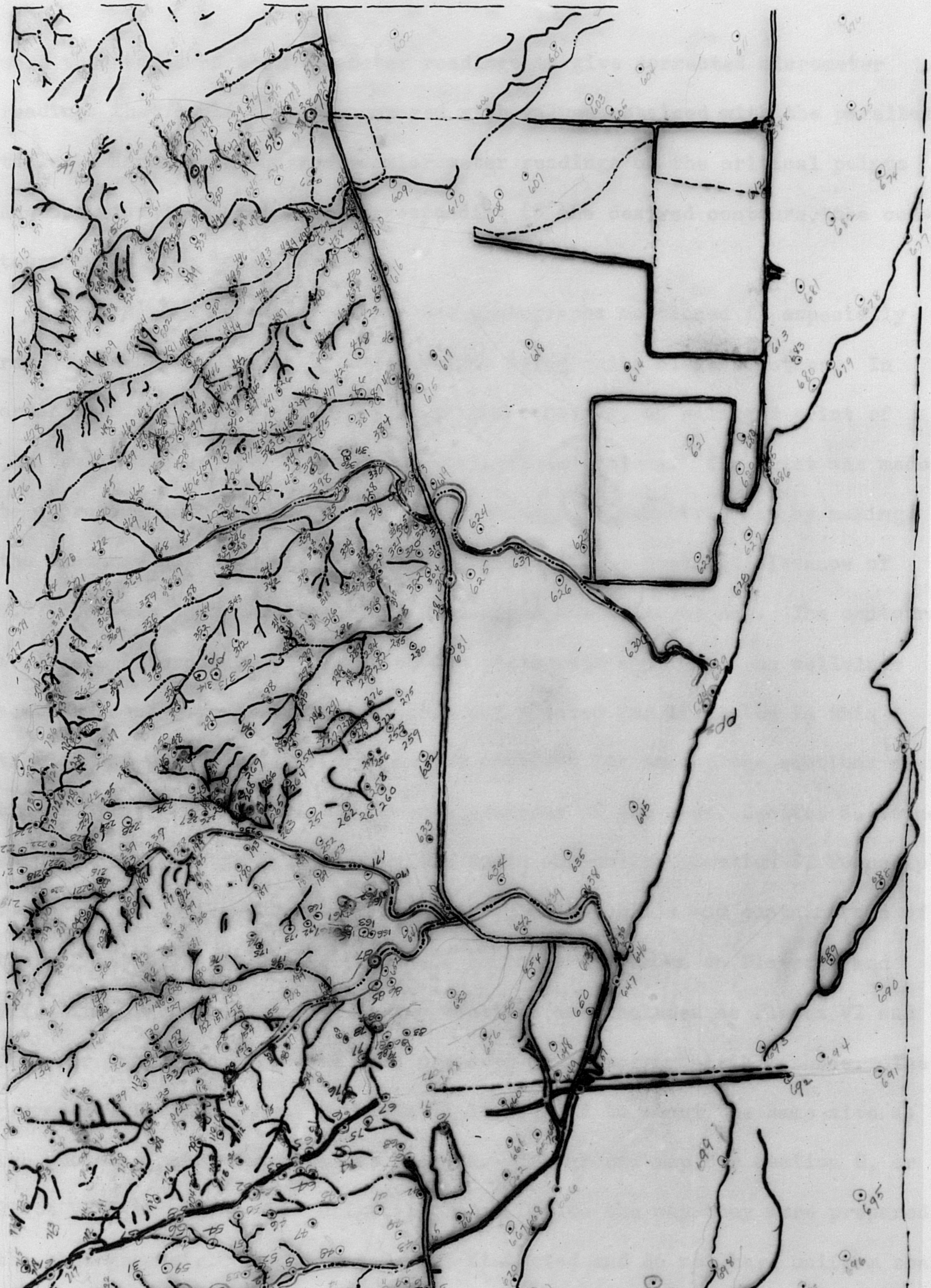
[1] Sanders, loc. cit.

EXPLANATION OF PLATE IV

Stereocomparagraph template

Stereocomparagraph template for area of overlap of photographs BND 92 17 and BND 92 18. Critical points are numbered from 1 to 736. The template has been slightly enlarged.

PLATE IV



were then added to the micrometer readings to give corrected micrometer readings that could then be compared with values obtained with the parallax tables. Knowing the corrected micrometer readings of the critical points and the micrometer readings corresponding to the desired contours, the contours could then be sketched in.

A portion of the area in the two photographs mentioned is especially rugged, resulting in the critical points being quite close together. In order to facilitate the drawing in of the contours, an enlarged print of the template was made by ordinary photographic methods. The print was made to approximately the same scale as the enlarged planimetric map by making the distance between the substitute centers fit the measured distance of 5.27" between the same two points taken from the enlarged map. The contours were then interpolated directly on the photograph and traced on cellulose acetate so they could be photographed and printed for inclusion in this thesis. It was decided to draw in the contours for one of the sections near the river, having some of the lower elevations of the area, Section 5, Township 14 North, Range 38 West, and the north one-half of Section 9, Township 14 North, Range 38 West, which is entirely in the hills and contains one of the highest hills in the area. These contours are shown on Plates V and VII. The ground maps for these two sections are included as Plates VI and VIII for comparison with the maps prepared by photogrammetric methods. The ground map for Section 5, or Plate VI is reduced to about the same size as the photogrammetric map of that section. The ground map for Section 9, or Plate VIII is included in original size. Due to the way they were prepared, the photogrammetric maps are somewhat distorted and do not have uniform scale.

ADDITIONAL DISCUSSION OF METHODS EQUIPMENT AND RESULTS

Rectoplanigraph

Enlarging the scale of the planimetric map about one and one-half times the scale of the photographs which were approximately 1 to 20,000, was an interesting application of the rectoplanigraph. The greater range of magnification provided by this instrument, and the relative ease with which it can be adjusted to increase the scale and correct for tip and tilt were demonstrated as making the instrument superior as one of the simple devices for projecting and copying planimetry to a predetermined scale. Due to the presence of the arm which contains the socket in which the ball of the easel rotates, the amount of tilt that can be corrected for is limited.

Correction Graph

Mr. Nowicki's statement in the Manual of Photogrammetry that "the accuracy of the final contoured templet sheet depends on the care with which the correction graph is constructed," was fully realized in this study.[1] Some difficulty was encountered with an initial correction graph and it was necessary to construct a second graph before satisfactory results were obtained.

Mr. Nowicki's conclusion to his chapter on the "Practical Applications of the Stereocomparagraph," in the Manual of Photogrammetry, is quoted:[2]

> It may be concluded that satisfactory contour maps can be compiled by use of the stereocomparagraph provided sufficient control is located on each photo and provided, further, that a datum plane correction graph, based upon information gathered from those points,

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[1] Nowicki, *loc, cit.*

[2] *Ibid.*, p. 492.

is also utilized. It must be remembered, however, that the resulting templet sheet will be in the form of a perspective view of the left hand photo and not an orthographic projection of the surface of the ground. For that reason, the separate templet sheets must be tied to each other by methods incorporating the principles of either the radial line, slotted template, celluloid template, or metal slotted arm process. Final compilation can then be carried out by means of reflecting projectors or by cutting in points from adjacent photographs.

If the master parallax tables are used, a relatively large number of vertical ground points, located at critical changes in topography, must be provided. Less points can be used if the values of (Δp), as obtained from the tables, are multiplied by the expression

$$\left[\frac{H}{H - h - \Delta h}\right]$$

If the values of differential parallax distances are computed from the formula $p = B_m \cdot (h)/(H-h)$ a relatively simple correction graph will result. Fewer points would be required and they would not necessarily have to be chosen at critical breaks in the topography. Less use of the "B-Y" motion screw would also result, especially if the photographs are oriented accurately along the stereo base line.

It should be pointed out here that the procedure of multiplying the values of Δp, as obtained from the master parallax tables was not followed. The practical impossibility of obtaining critical breaks in slope has already previously been mentioned. Further reference to this conclusion is made on page 24.

Scale of Planimetric Map

The actual scale of the planimetric map was determined by scaling a distance along the centerline of the Kingsley Dam and comparing with actual distance taken from plans. One of the points used was the point of intersection of the centerline of the penstock from outlet tower to stilling basin and the centerline of the dam. The other point used was the point of intersection of the centerline of the Union Pacific Railroad with the centerline of the dam. These two points were toward the extremities of the centerline of the dam. The stationing of the two points along the centerline were 11 + 75 and 87 + 02.5, making the actual distance between them 7,527.5 feet. The scaled distance taken from the planimetric map was 6.70 inches. The scale of the map was, therefore, one inch equals 1,123.5 feet or 1 to 13,482. It would probably be sufficiently accurate, all things considered, to specify the scale as one inch equals 1,125 feet or 1 to 13,500.

The distance between the same two points on the centerline of the dam as scaled from photograph BND 176 159 is 4.49 inches. This would make the scale of this photo 1" = 1,676.5 feet, or 1 to 20,118. This should be very nearly the scale of the first photograph of the strip BND 176 158, as the distances between the principal points or substitute centers was practically the same on both photos. According to the scales obtained for the planimetric map and the photo, the enlargement obtained in the planimetric map is 1,676.5 ÷ 1,123.5, or about 1.49 times. This checks the original intention to enlarge the scale of the map one and one-half the original mean scale of photographs 157 and 158.

Contour Comparison

As can be observed by comparing the contour lines obtained by photogrammetric methods with the same contour lines obtained by ground methods, the results obtained by the two methods agree fairly well. Comparing Plates V and VI for Section 5, the 3200-foot contour line is drawn a little farther south in the southwest corner and extends farther north near the half-section line. The 3220-foot contour line is pulled farther north near the half-section line and southeast corner of the section on the photogrammetric map. Elsewhere the agreement is good. It is possible that the shapes of the contour lines on the two maps would have corresponded more closely if additional critical points had been located on the photographs or the floating dot of the stereocomparagraph had been used.

While correcting the micrometer readings for the critical points used in the north half of Section 9, a slight error in the correction graph was discovered which was probably a major cause of the disagreement of the contour lines in Section 5. The corrected elevations were found to average about twenty feet too high in Section 9. After examining the micrometer readings of the vertical control points used in making the second correction graph, the difficulty was revealed. These readings had been taken sometime later than the micrometer readings for the critical points were taken. Readings made on the same points on both occasions, when compared, revealed an average discrepancy in the area of about 0.10 mm. The variation was probably due to a change in the orientation of the stereocomparagraph, or a slight change in the relationship of the two overlapping photographs with respect to each other. Actually, the two photos were fastened down in the same position during the elapsed time, while the stereocomparagraph had been removed and had to be set up and reoriented before the second set of micrometer readings were made for the vertical control points of the new correction graph. After the corrected micrometer readings were all reduced about 0.10 mm., fairly accurate contours were sketched in.

The contours sketched in for Section 9 were in the same relative positions as the same contour lines on the ground map. This can be observed by comparing the photogrammetric and ground maps appearing in Plates VII and VIII. The ground map is included in original scale as Plate VIII. The shapes of the contour lines on the two maps do not agree. This is understandable, and the disagreement is again probably due to the same causes as set forth in the preceding comparison made for Section 5.

One of the high points of the entire area appears in Section 9 with an elevation of 3,412.5 feet on the ground map. A micrometer reading on a nearby point in the same area revealed an elevation of 3,408 feet which is very good agreement. Elsewhere, agreement is good.

Focal Length and Flying Height

Information obtained from the Production and Marketing Administration office in Manhattan, Kansas, as revealed from specifications governing aerial photography of the Agricultural Adjustment Administration at the time the photographs used in this study were taken, confirmed the assumption made for the focal length of the camera and the flying height obtained. These specifications required a focal length of about 8 inches and a flying height that would produce a scale of 1 to 20,000. A flying height of 18,000 feet would produce approximately such a scale for the ground elevations encountered. An extract from these specifications follows:[1]

> Standard Specifications for Aerial Photography for general map work and land studies, approved for Federal use on May 27, 1937, with deviations authorized by the Secretary of the Treasury on November 9, 1939, for the exclusive use of the United States Department of Agriculture.
>
> Plane and Camera Crew
>
> The camera shall be so equipped with a lens which meets the following requirements as indicated by a report, or a photographic copy thereof, of a test made by the National Bureau of Standards: For a camera using 7 by 9 inch film and having a lens of approximately 8 inch focal length, the distortion shall not exceed plus or minus 0.004 inch (plus or minus 0.10 mm) at 30° from the center of the field. For a camera using 9 x 9 inch film and having a lens of approximately 8 inch focal length, the distortion shall not exceed plus or minus 0.004 inch (plus or minus 0.10 mm) at 35° from the center of the field.

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[1] Specification A-AP-1101. Specifications for a Precision Airplane Mapping Camera. Washington: Government Printing Office, Nov. 18, 1939.

CONCLUSION

Considering the extent of the area used and equipment available and the difficulties encountered, the results obtained were very satisfactory.

Had it been possible to obtain extensive ground control and independent control points for the datum plane correction graph, the comparison made between the photogrammetric maps and those obtained by ground methods would be of greater significance.

It is not intended here to establish the fact that photogrammetric methods are superior to ground methods. The advantages of photogrammetry have been well established. Many examples prove that photogrammetric maps are less expensive and can be prepared in much less time than similar ground maps when the better types of stereoscopic plotting instruments with experienced operators are used. However, the possibilities of the simpler types of photogrammetric equipment used for instructional purposes in most schools have been demonstrated. It is the opinion of the writer that the equipment used possesses certain advantages over ground methods, providing adequate ground control is available and for large areas would be less expensive and faster. However, for the area used, it is doubtful that photogrammetric methods, with the equipment available, would be any faster.

It has been shown that the stereocomparagraph used with a carefully prepared correction graph does furnish accurate contours.

The writer has succeeded, in part, in comparing the two methods of preparing topographic maps and increased his knowledge of the methods and equipment used in teaching photogrammetry.

ACKNOWLEDGEMENTS

The writer wishes to express appreciation for the patience, suggestions, and encouragement offered by Dr. Reed F. Morse and Professor L. V. White, of Kansas State College, during the course of this investigation. Also, acknowledgement is made to Professor Lawrence J. Perez, Professor of Photogrammetry at Pennsylvania State College, for his sincere interest in this project and for furnishing suggestions and printed information which were instrumental in overcoming some of the main difficulties encountered.

Acknowledgement and appreciation are also accorded the following individuals. Mr. George E. Johnson, former Chief Engineer of the Central Nebraska Public Power and Irrigation District, and Mr. E. E. Flanagan, designer for the same organization, cooperated in selecting the area and furnished an initial set of maps. Mr. Bernard Donelan, Resident Engineer-Superintendent of the Kingsley Dam, supplied additional plans and information which contained desired elevations and stationing of points on the dam and appurtenant structures.

Among those who offered opinions on the merits of the proposed project were Professor Earl Church, Professor of Photogrammetry of Syracuse University, Syracuse, New York, and Mr. D. H. Harkness, Sales Manager for W. & L. E. Gurley, Troy, New York, and former Professor of Surveying at the University of Nebraska.

To Mrs. Mary Moeller, my wife, for her assistance in typing this thesis and her aid and helpful suggestions throughout the entire project.

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A P P E N D I X

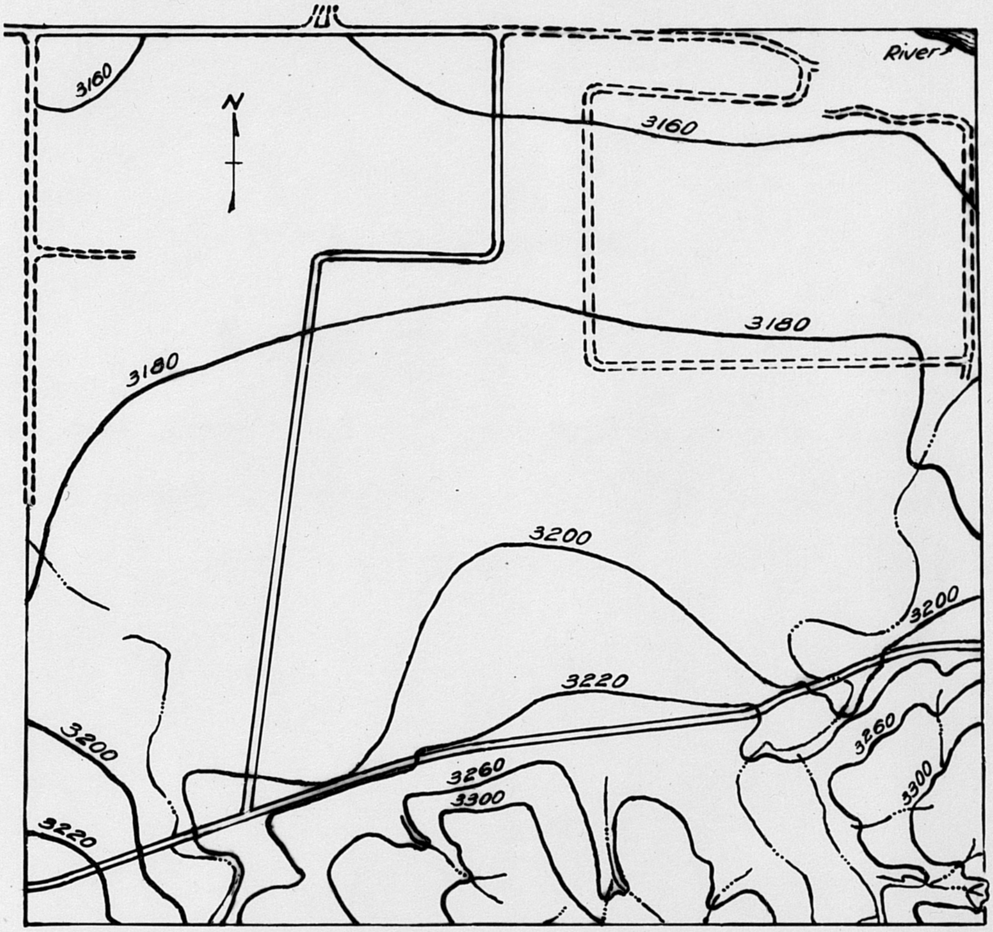
EXPLANATION OF PLATE V

Topographic map, Section 5 (photogrammetric)

Topographic map of Section 5, Township 14 North, Range 38 West, prepared by photogrammetric methods.

Contour interval is 20 feet on flatter slopes and 40 feet on steep slopes. The scale is approximately the same as the scale of the planimetric map of Plate II, but is not uniform.

PLATE V

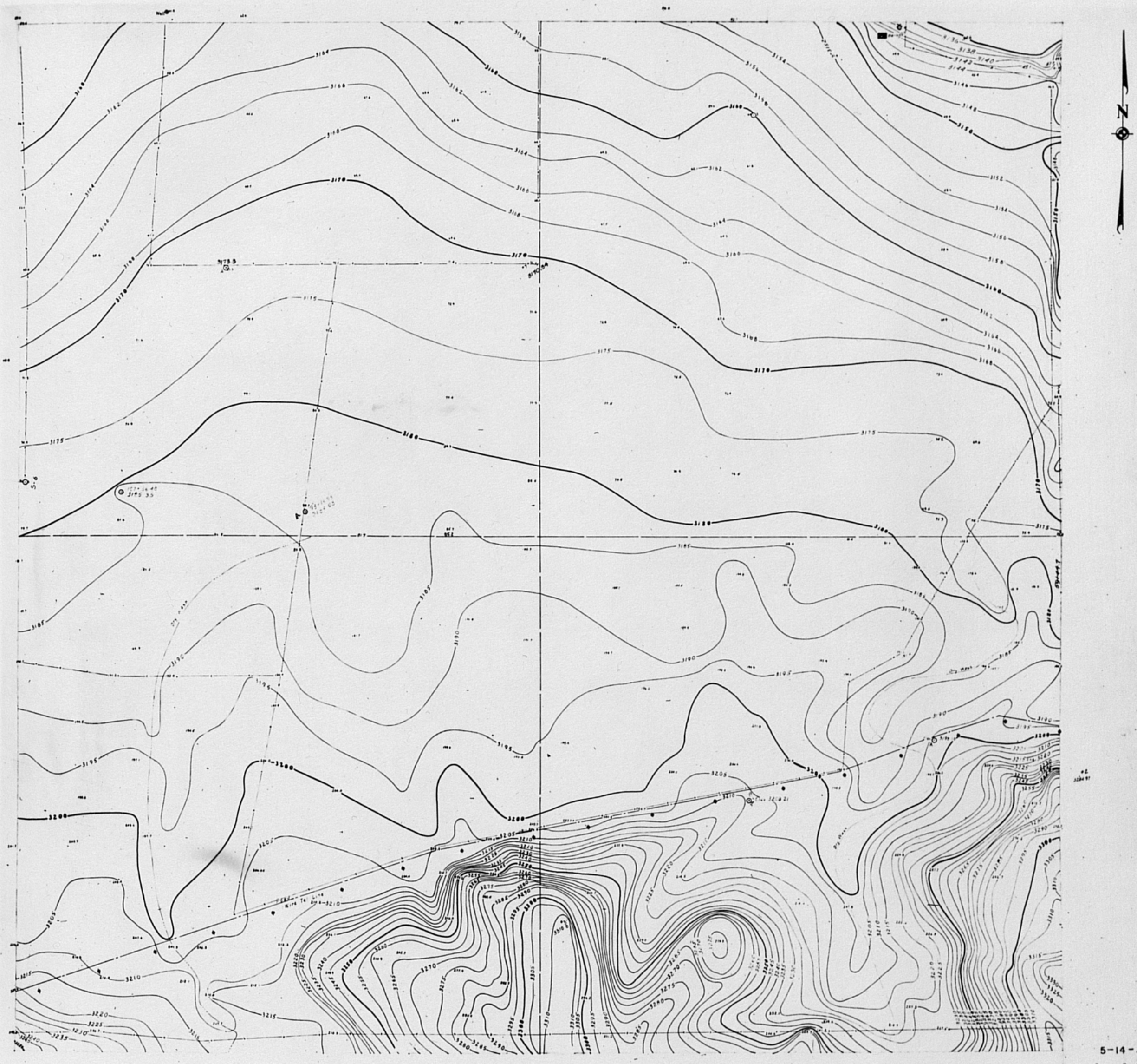

River
N
3160
3160
3180
3180
3200
3200
3200
3220
3220
3260
3300
3260
3300

EXPLANATION OF PLATE VI

Topographic map, Section 5

Topographic map of Section 5, Township 14 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE VI



5-14-38

Drawn By AHW

EXPLANATION OF PLATE VII

Topographic map, Section 9 (photogrammetric)

Topographic map of Section 9, Township 14 North, Range 38 West, prepared by photogrammetric methods.

Contour interval is 40 feet. The scale is approximately the same as the scale of the planimetric map of Plate II, but is not uniform.

Note: A 20-foot contour interval is used in the vicinity of the highest point of the area.

PLATE VII


N
3260
3300
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3340
3300
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3300
3380
3400
3340
3300
3260
3220
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3220
3260
3300
3260
3300
3340
3380
3380
3380
3260
3300
3300
3220
3260
3300

EXPLANATION OF PLATE VIII

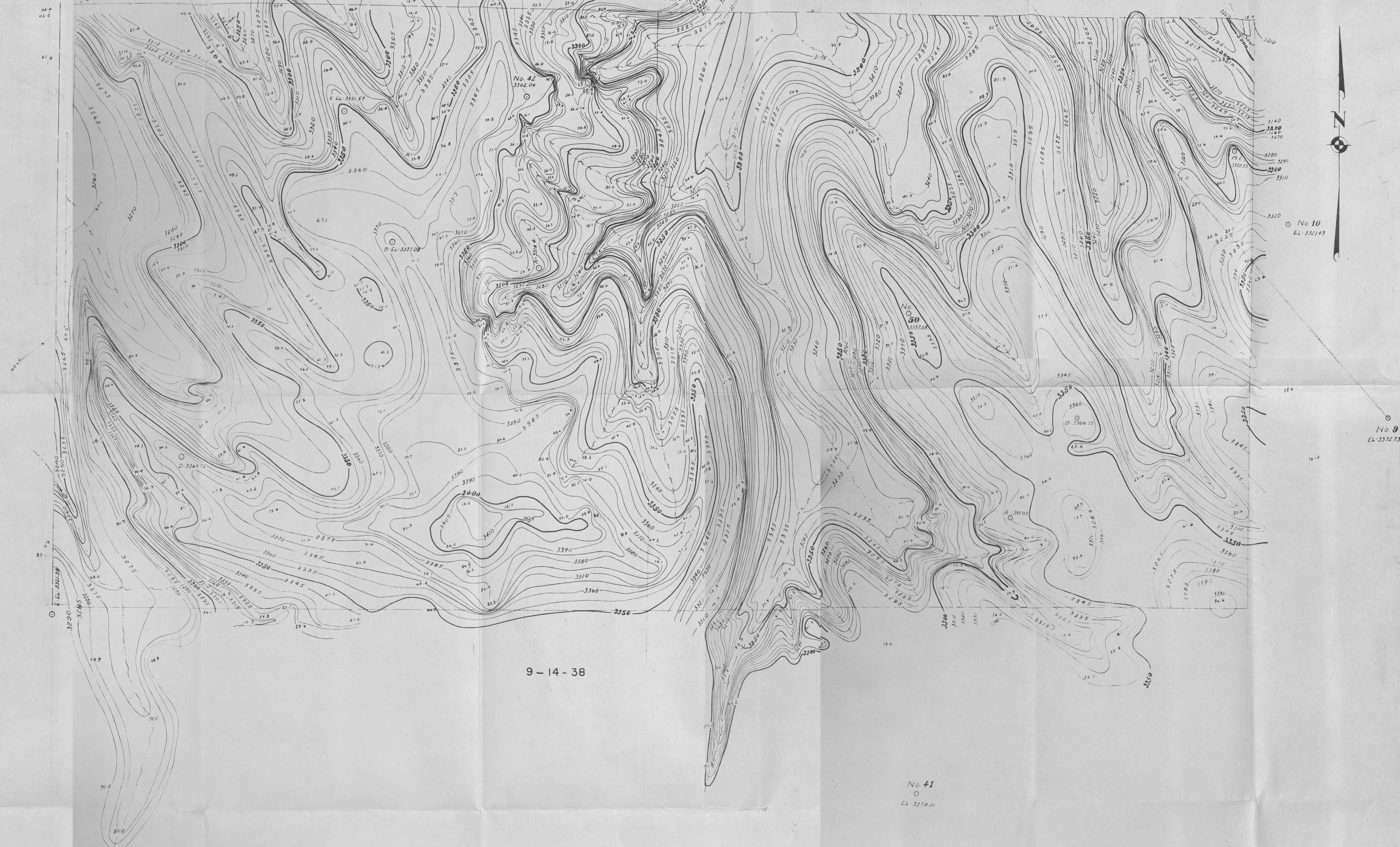
Topographic map, Section 9

Topographic map of Section 9, Township 14 North, Range 38 West, prepared by ground methods.

PLATE VIII

Topographic map, Section 9

PLATE VIII



9-14-38

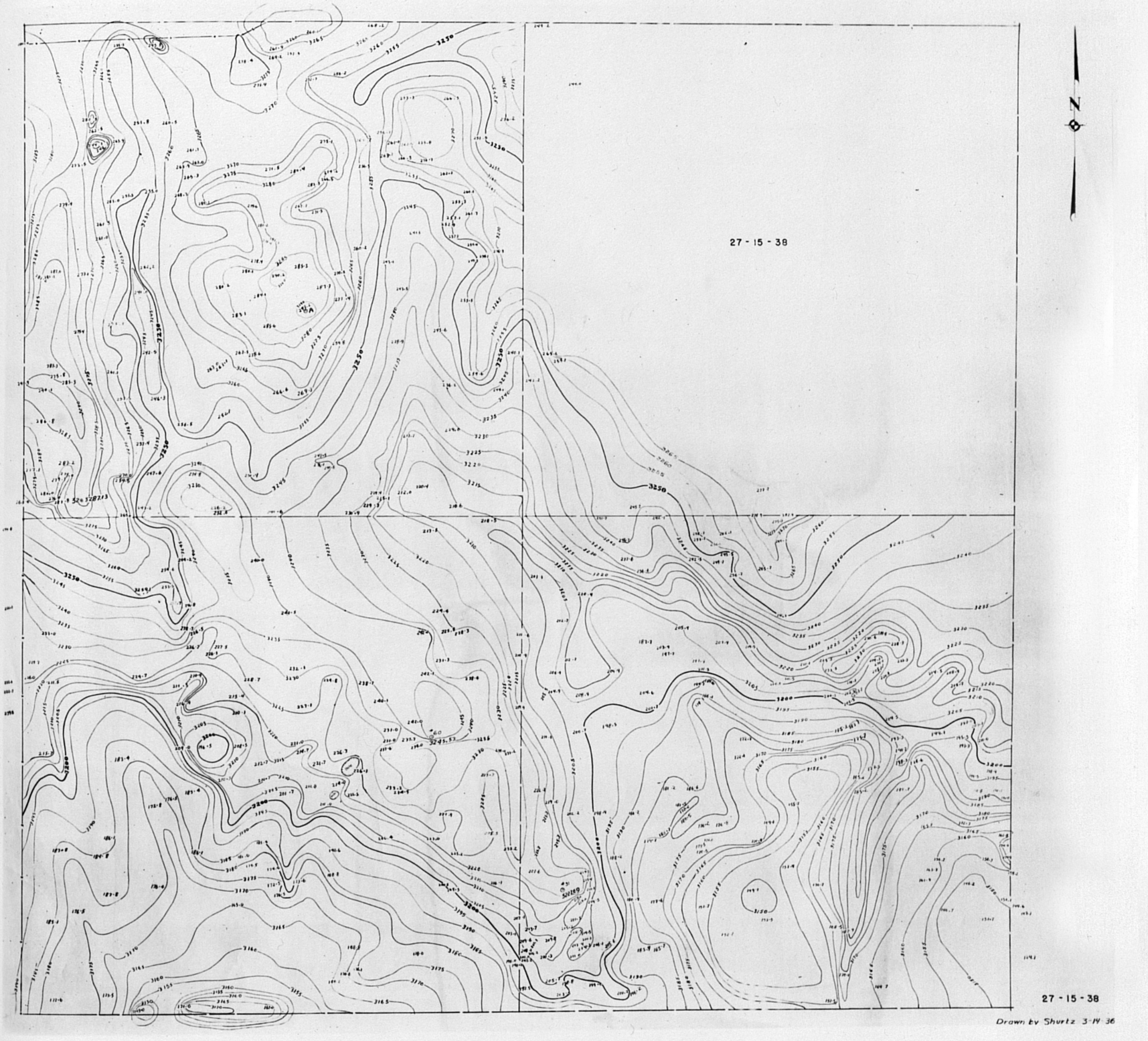
Drawn by Schlaefli 3-12-36

EXPLANATION OF PLATE IX

Topographic map, Section 27

Topographic map of Section 27, Township 15 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE IX

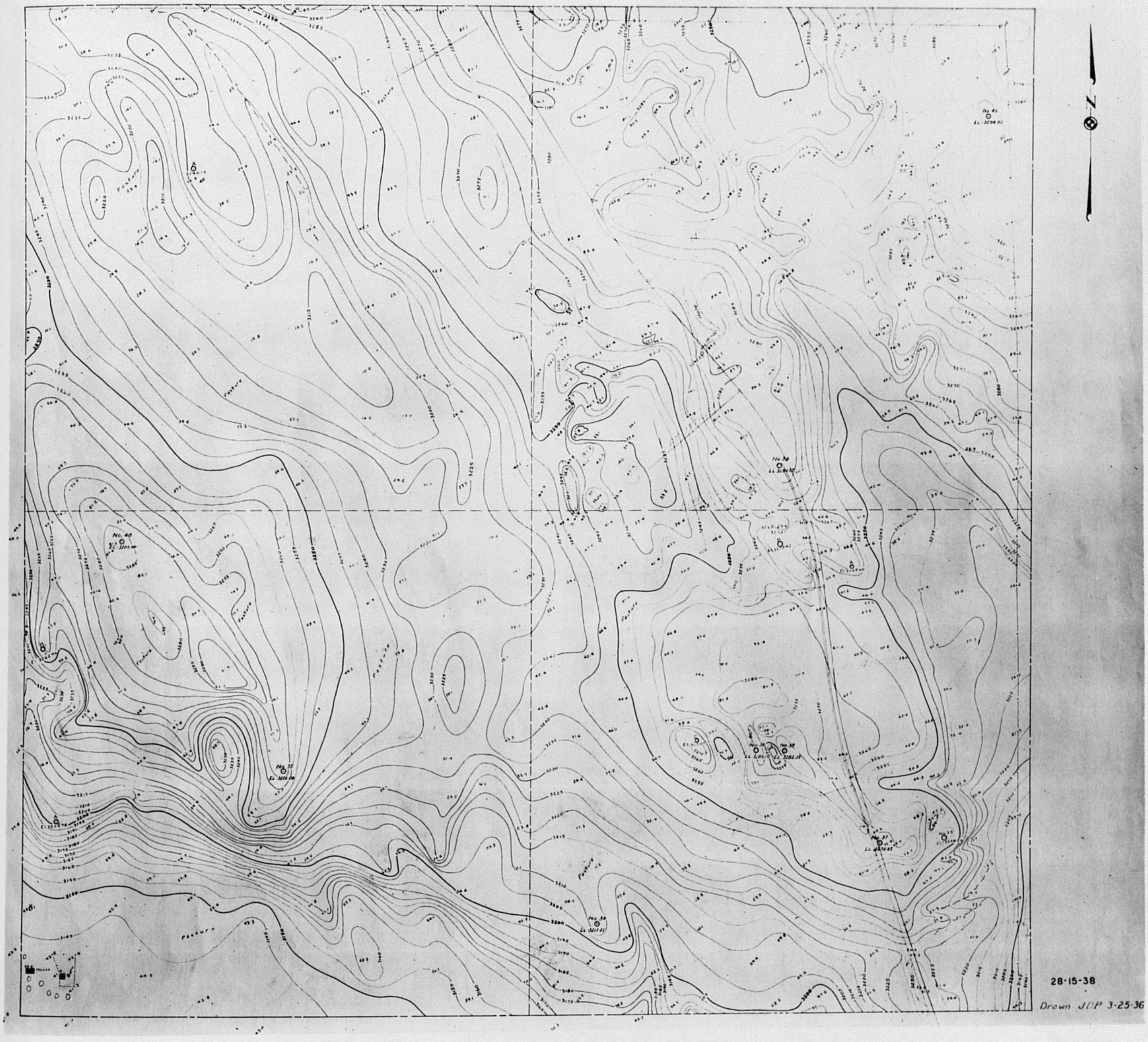


EXPLANATION OF PLATE X

Topographic map, Section 28

Topographic map of Section 28, Township 15 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE X

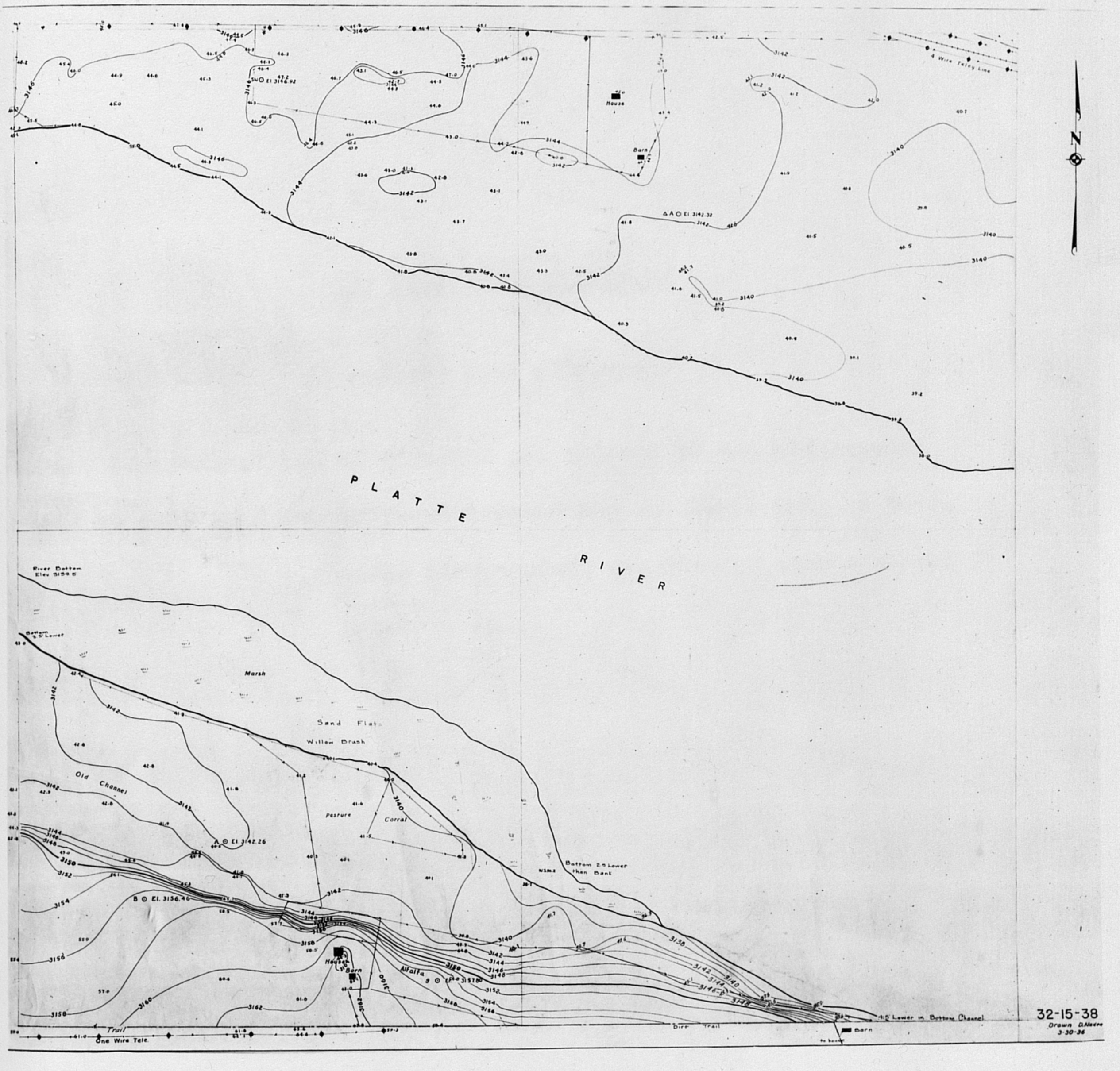


EXPLANATION OF PLATE XI

Topographic map, Section 32

Topographic map of Section 32, Township 15 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XI

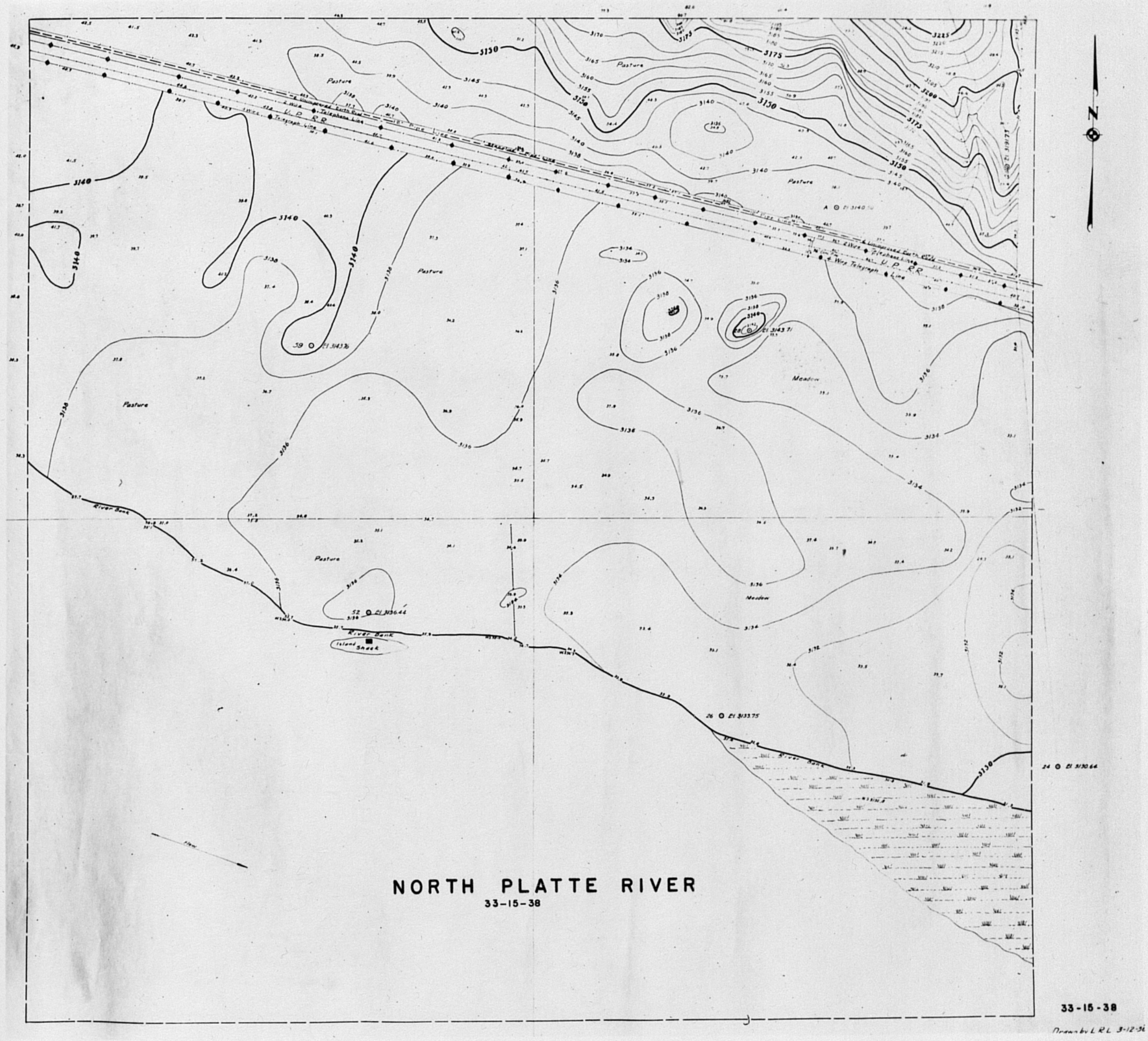

PLATTE RIVER
Marsh
Sand Flats
Willow Brush
Old Channel
Pasture
Corral
Alfalfa
House
Barn
Trail
One Wire Tele.
Dirt Trail
4 Wire Tele. Line
River Bottom Elev 3159.8
Bottom 2.5' Lower than Bank
4.5' Lower in Bottom Channel
32-15-38
N

EXPLANATION OF PLATE XII

Topographic map, Section 33

Topographic map of Section 33, Township 15 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XII

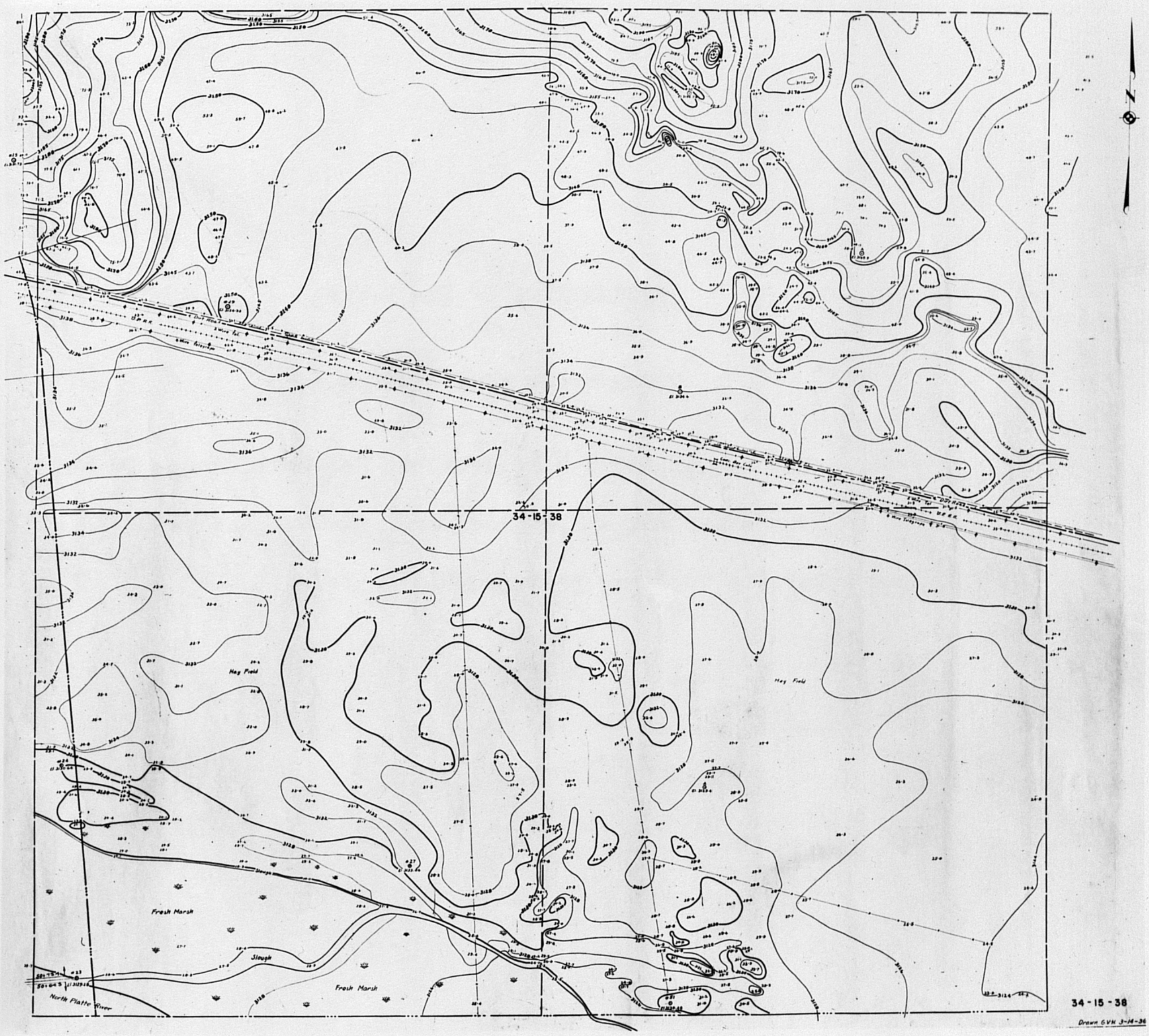

Pasture
Meadow
U. P. R.R.
River Bank
Island
Shack
NORTH PLATTE RIVER
33-15-38
N
33-15-38

EXPLANATION OF PLATE XIII

Topographic map, Section 34

Topographic map of Section 34, Township 15 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XIII


34-15-38
Hay Field
Hay Field
Fresh Marsh
Slough
Fresh Marsh
North Platte River
34-15-38

EXPLANATION OF PLATE XIV

Topographic map, Section 2

Topographic map of Section 2, Township 14 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XIV


NORTH PLATTE RIVER
MAIN CHANNEL
DIRECTION OF FLOW
NORTH CHANNEL
Crest Spillway
3123.25
2-14-38
FMW

EXPLANATION OF PLATE XV

Topographic map, Section 3

Topographic map of Section 3, Township 14 North, Range 38 West, prepared by ground methods.

PLATE XV

Topographic map, Section 3

3-14-38

DRAWN BY AHW 4-16-36

EXPLANATION OF PLATE XVI

Topographic map, Section 4

Topographic map of Section 4, Township 14 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XVI

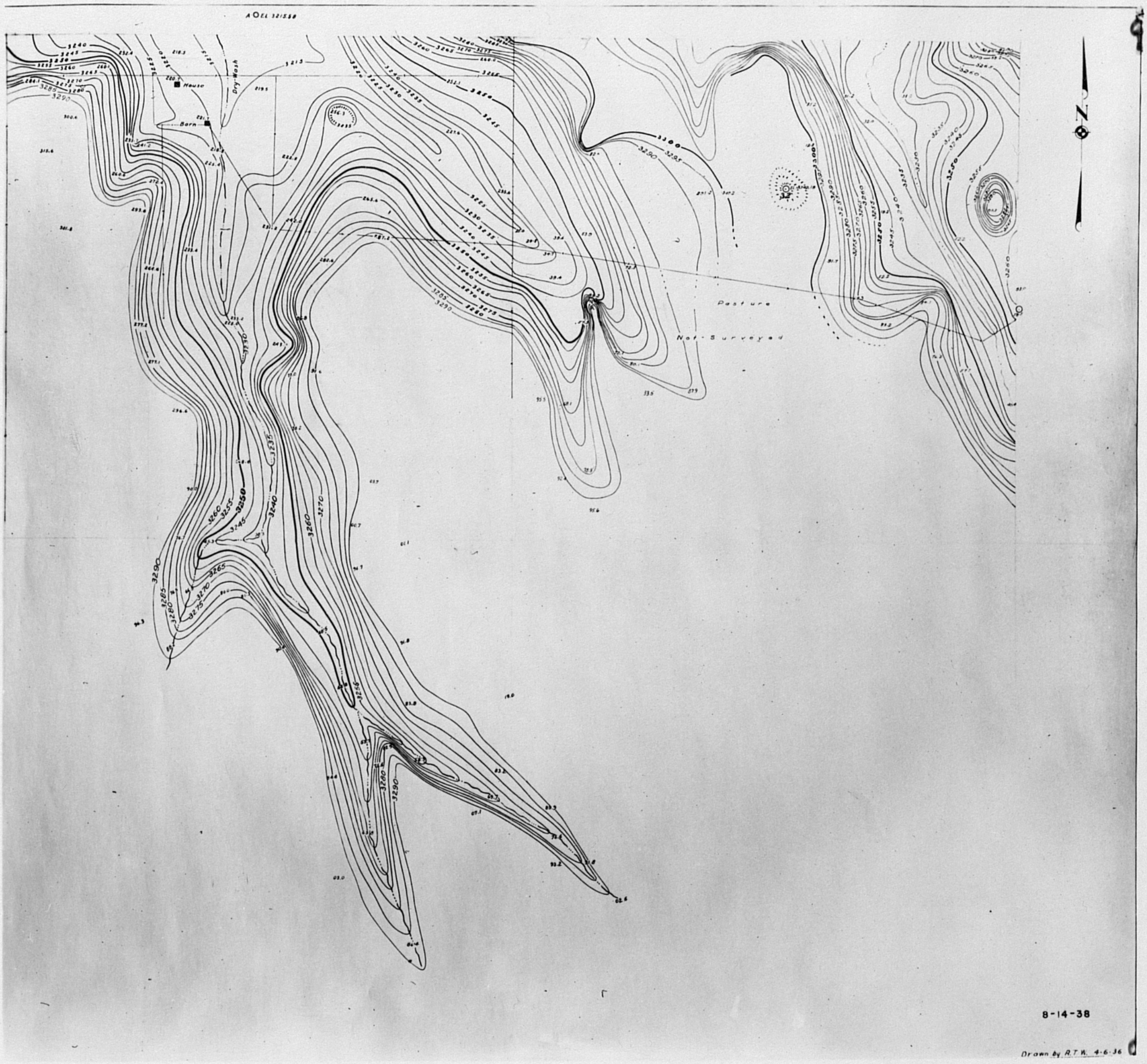

NORTH PLATTE RIVER
4-14-38
River Bottom El 3135.5
9.0' Lower than bank
Alfalfa
Cultivated
Corn
Meadow
Private 10' Unimproved Dirt Road
4-14-38

EXPLANATION OF PLATE XVII

Topographic map, Section 8

Topographic map of Section 8, Township 14 North, Range 38 West, prepared by ground methods and reduced from the original size of about 27 inches square by ordinary photographic methods.

PLATE XVII


House
Barn
Dry Wash
Pasture
Not Surveyed
N
8-14-38
Drawn by R.T.W. 4-6-36

EXPLANATION OF PLATE XVIII

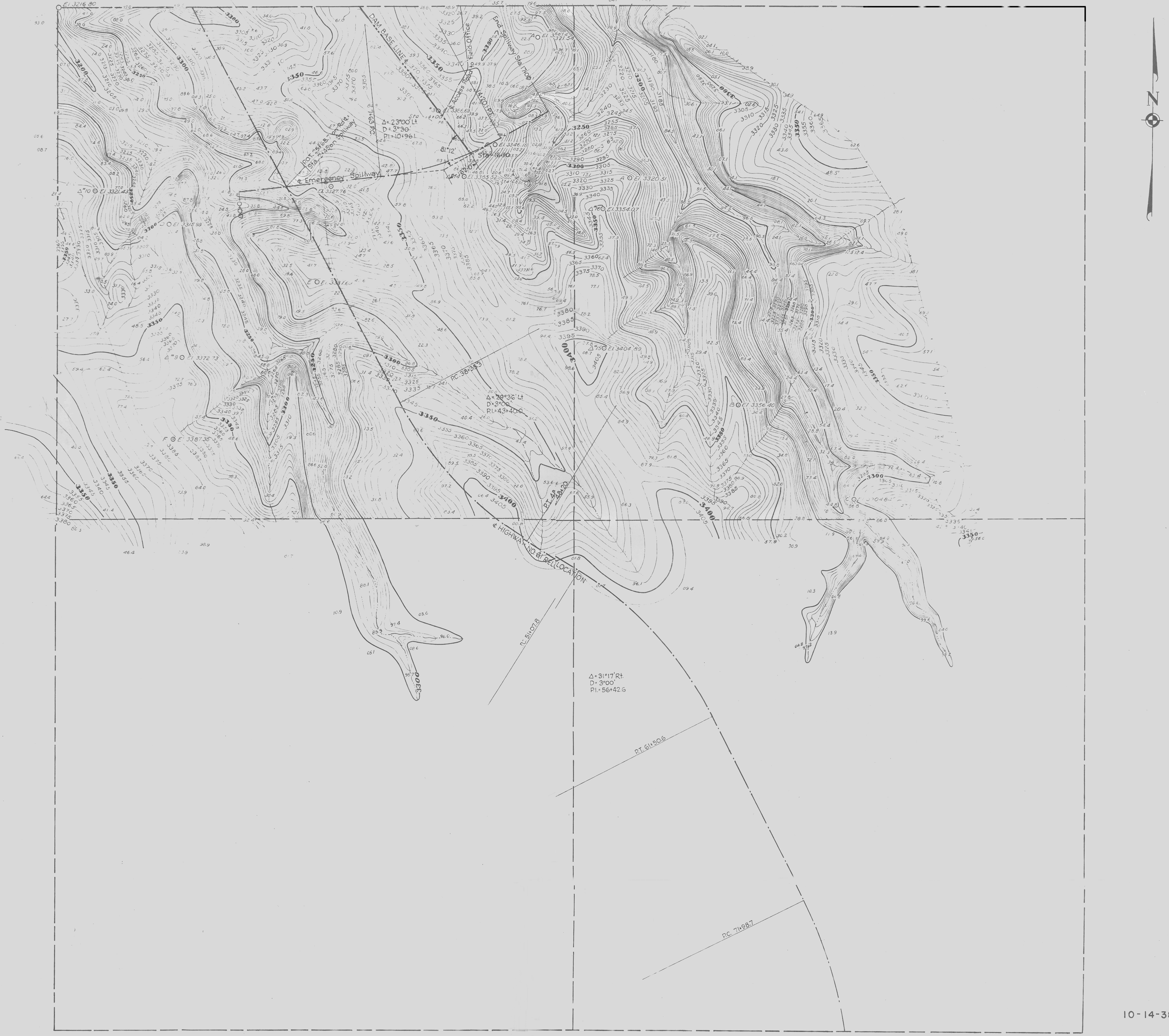
Topographic map, Section 10

Topographic map of Section 10, Township 14 North, Range 38 West, prepared by ground methods.

PLATE XVIII

Topographic map, Section 10

PLATE XVIII



10-14-38

Drawn by J.C.M. 4-18-36

PHOTOGRAMMETRIC STUDY OF AN AREA
PREVIOUSLY MAPPED BY GROUND METHODS

by

CLIFFORD MERRILL MOELLER

B. S., University of Nebraska, 1936

AN ABSTRACT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

PURPOSE

The purpose of this investigation was to make planimetric and topographic maps, using photogrammetric methods, of an area previously mapped by ground methods. By so doing, the writer expected to become familiar with the fundamental principles of photogrammetry and the equipment used in teaching this subject.

MAPS AND PHOTOGRAPHS USED

Topographic maps prepared by ground methods were obtained from the Central Nebraska Public Power and Irrigation District at Hastings, Nebraska, for an area around the site for the Kingsley Dam near Ogallala, Nebraska. Twelve separate map sheets were obtained, each covering a full or half-section of land. These maps were to a scale of one inch equals 200 feet and the contour interval was five feet for the most part, but, in some cases, two feet. Three of the full size sheets are included in the thesis. The remaining sheets were reduced to about six by six inches and are all included.

Six nine by nine inch, overlapping vertical photographs were obtained from the Agricultural Adjustment Administration. These photos covered the same area included in the ground maps, plus several additional sections. The scale of the photos was approximately 1 to 20,000.

CONTROL

Several ground control points were taken from the plans for the Kingsley Dam since the dam appears, under construction, in the center of the area.

Properly located points were marked on the photographs and used as secondary or picture point control.

Both ground and secondary control points were plotted to the mean scale of two of the photos, using an application of the radial line method. The control sheet was then enlarged one and one-half times by a rather unique method illustrated in Plate I of the thesis.

PLANIMETRY

A planimetric map of the entire area was made by utilizing the rectoplanigraph. The planimetry was fitted to the enlarged control sheet and the various sections for which ground maps were secured were outlined and designated. The completed planimetric map appears as Plate II in the thesis.

The rectoplanigraph is a handy instrument, used, among other things, to trace planimetric detail directly from aerial photos free from tip and tilt distortion. This instrument will also enlarge up to two and one-half times the scale of the photograph.

CONTOURING

The stereocomparagraph, a simple stereoscopic plotting instrument, was employed in obtaining the contour lines. The stereocomparagraph is, primarily, an instrument consisting of a mirror, stereoscope, a measuring device, a drawing attachment, and a parallel motion mechanism. Aside from the above features, it also includes an attached lighting system.

Two overlapping photographs, properly oriented beneath the stereoscope, produce a three-dimensional image model of the ground surface. A fused floating dot is made to appear to rise or fall with respect to the model by means of a screw-type micrometer. The micrometer can be read or set to the nearest .01 milimeter. A micrometer reading for a desired contour line can be determined. If this reading is set on the micrometer and the floating dot is maintained in contact with the three-dimensional model, the tracing arm will trace the contour or form line. Without the aid of a correction graph, only form lines can be obtained with the stereocomparagraph.

A datum plane correction graph for two of the overlapping photographs was prepared and successfully used in this study. When preparing such a graph, corrections are first determined for a number of properly selected vertical control points and the correction graph is constructed using these values. The elevations of the vertical control points used in making the correction graph of this thesis were taken from the ground maps. This meant that the vertical control points had to be selected that could be identified on the maps rather than in locations desired for best accuracy.

When using a correction graph, the accuracy of the resulting contour lines depends upon the number and location of the control points and the care with which this graph is constructed.

The correction graph compensates for distortions due to tip or tilt, irregular shrinkage of negatives and prints, variations in flight altitude, vacuum plate failure, lens distortion, and also distortions arising from errors existing in the present widely-used parallax tables.

The correction graph appears as Plate III of the thesis.

Instead of using the floating dot, micrometer readings were taken to as many critical points on streams, ridges, etc., as could be identified on the photos. These points, along with the drainage lines, were traced on a template, a copy of which appears as Plate IV of the thesis. Corrections from the correction graph were applied to the micrometer readings and the corrected readings were recorded opposite corresponding points on the stereocomparagraph template. Micrometer readings corresponding to the desired contour lines were obtained by referring to the stereoscopic parallax tables. Contour lines were then sketched in as in logical contouring.

Contour lines were drawn for Section 5, most of which is relatively flat and low, and for the north half of Section 9, which is rugged and contains one of the high points of the map with an elevation of 3,312.5 feet. A contour interval of 20 feet was used where the slope is gradual and near the high point in Section 9, and a 40-foot contour interval was used elsewhere. Each section is included as a separate plate.

The photogrammetric maps can be compared with ground maps of the same section shown on additional plates. Discrepancies in location of the contour lines on the two maps is attributed to slight errors in the correction graph. Differences in shape are probably due to the inability to obtain sufficient and properly located critical points.

DETERMINATION OF FLYING HEIGHT

It was necessary to determine the flying height of the plane in order to make the computations required for the construction of the correction graph. The focal length of the camera was assumed to be eight inches and the flying height was determined by a method of repeated calculations. Several trials were made in one strip of three photos and the average flying height was used in preparing a correction graph for the area of overlap of two of the photos.

The method of repeated calculations was obtained from Professor Perez, Professor of Photogrammetry of Pennsylvania State College. According to Professor Perez, the method was originated by Professor Earl Church, Professor of Photogrammetry at Syracuse University.