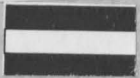


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Report on

PHOTOGRAMMETRIC DETERMINATION OF RELATIVE SNOW AREA

By

A. H. Barnes

for

U. S. Forest Service

Rocky Mountain Forest and Range Experiment Station

June 1970

ENGINEERING RESEARCH

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REPORT

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## INTRODUCTION

This is a report of a photogrammetric and computer procedure for the evaluation of relative snow cover in a limited area of a drainage basin. The primary goal was to provide a more precise and accurate evaluation than previously used. An additional benefit was to reduce the time required for each determination.

The measurements were all made on photographs number 52 and 53 of the Lexen Creek index area. The camera focal length was nominally 8 1/4 inches.

The observational and computational procedures were based on several simplifying assumptions. Future applications of the basic procedure could include the effect of these assumptions.

Measurements on the stereoscopic transparencies were made on a Wild STK-1 stereocomparator with punched card output. The least count of this instrument is one micrometer\* (1/25,400 inch). The computations were made on a Control Data Corporation 6400 Computer using the Fortran language.

## PHOTOGRAMMETRIC PRINCIPLES

There are a set of unique relationships between the position of a photographic image and its spacial position. These relationships are functions of;

1. The coordinates of the image of the same object on overlapping photographs,

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\* previously the micron

2. The focal length of the camera lens,
3. The distance between the camera lens for the two exposures,
4. The elevations of the exposure stations above an elevation datum if the elevation of the space position is to be determined, and
5. The direction of the camera's optical axis at the two exposure stations.

For the photography available for this study, some of the above information was unavailable or could not be evaluated. Thus the following assumptions were made:

1. The optical axis at each exposure station was vertical.
2. The elevations of the exposure stations for overlapping views, were the same.

For the above conditions the relationship between the photographic image and space coordinates can be stated as:

$$X = x_1 \frac{B}{x_1 - x_2} ; Y = y_1 \frac{B}{x_1 - x_2} ; H - h = f \frac{B}{x_1 - x_2}$$

in which

X and Y are the space coordinates of the ground point in the horizontal plane referred to the principal point

$x_1$  and  $y_1$  are the image coordinates of the same point on the left photograph of the stereo pair

$x_2$  is the x-coordinate of the same point on the right hand photograph of the stereo pair

B is the horizontal distance between exposure stations

H is the elevation of the exposure station above an arbitrary station

$h$  is the elevation of the space object above the datum

$f$  is the focal length of the camera lens.

The term  $(x_1 - x_2)$  represents the difference in the x-position of an image in the overlapping area of the photographs. It is usually referred to as the x-parallax. This term will be used hereafter and symbolized as  $px$ .

Since the purpose of this study was to measure only relative horizontal areas, only the first two equations are of interest.

### COMPUTATIONAL PROCEDURES

The preceding development permits the evaluation of the coordinates of discrete points on the boundary of an enclosed ground area. The enclosed area can then be computed by the equation:

$$A = \frac{1}{2} [x_1(y_2 - y_n) + x_2(y_1 - y_3) + x_3(y_2 - y_4) + \dots + x_n(y_{n-1} - y_1)]$$

Expressed in a more systematic form, the area is

$$A = \frac{1}{2} \begin{vmatrix} x_1 & x_2 & x_3 & \dots & x_n \\ y_1 & y_2 & y_3 & \dots & y_n \end{vmatrix} \begin{matrix} x_1 \\ y_1 \end{matrix}$$

in which the quantities on the diagonals downward-to-the-right are multiplied and added, while the quantities on the diagonals upward-to-the-left are multiplied and negatively accumulated. The sign of the final accumulation will be positive or negative depending on whether the order of the coordinates was taken in a clockwise or counterclockwise direction around the area. The absolute value of the resulting computation is the desired area.

It was not possible to determine the area in conventional units of ground area since the aerial-base (B) was not known nor could it be determined. However, since only relative area was desired, the following transformation was performed:

$$X' = \frac{X}{B} = \frac{x}{px} ; Y' = \frac{Y}{B} = \frac{y}{px}$$

Since  $x$ ,  $y$  and  $px$  are measured quantities,  $X'$  and  $Y'$  can be evaluated and used for a dimensionless area determination. From the dimensionless area of the snow and the gross area, the percent area of snow could then be determined.

#### MEASUREMENT PROCEDURES

The measurement of the  $x$ ,  $y$  and  $px$  values was performed on a stereocomparator manufactured by Wild Co. and designated as STK-1. This device permits the stereoscopic viewing of overlapping diapositives and the measurement of photograph image positions with a least count of one micrometer. The values are automatically digitized and at the command of the operator, punched onto punch cards.

The procedure for mounting the diapositives on the STK-1 and obtaining the correct orientation is presented in Table 1.

The procedure for preparing the digitizer, card punch, and STK-1 for operation is presented in Table 2.

The operator was instructed to measure the position of points on the boundary of each area. The points selected were those which best described the area as a closed polygon. Each point was measured once during a delineation of a given area.

TABLE 1

STEREOCOMPARATOR**Mounting and Orientation of Diapositives**INTERIOR ORIENTATION

1. Place **plate holder** on viewing box.
2. Check for **correct** positioning of mounting plate studs in holes in viewing **box**.
3. Lay **diapositive** on plate holder with emulsion down.
4. Orient **diapositive** for stereo viewing.
5. Align **diapositive** fiducial marks with reference lines on plate holder (**use** magnifying glass).
6. Clamp **diapositive** to holder with knurled knobs.
7. Repeat for **other** plate holder and stereo diapositive.
8. Mount **plates** on stereocomparator.
9. Insure **correct** mating of plate holder studs and matching holes in plate holder carrier.

RELATIVE ORIENTATION

10. Position **the left** measuring mark on the left principal point (**x** and **y** motions).
11. Position **the right** measuring mark on the right principal point (**px** and **py** motion).
12. Check **position of** both measuring marks on their respective principal points.
13. Set desired initial coordinates on the digitizer.
14. With the **px-motion**, move the right diapositive to approximate stereo **viewing of** the left diapositive principal point and its conjugate point on the right diapositive.
15. Rotate **the right** diapositive (K-motion) for coincidence of the two images.
16. With the **x-motion**, move both diapositives to approximate stereo **viewing of** the right diapositive principal point and its conjugate point on the left diapositive.
17. Rotate **the left** diapositive (K-motion) for coincidence of the two images. Adjust **px-motion** as necessary to obtain stereo viewing.

CHECK

1. Position of head rest for comfort.
2. Interpupillary distance for equal fields of view.
3. Eyepiece focus for each measuring mark.
4. Squint control for zero py.
5. Desired magnifications for viewing and measuring mark.
6. Illumination of each diapositive.
7. Condition of digitizer.
8. Condition of card punch.
9. Proceed.

TABLE 2

PROCEDURE TO SET UP DIGITIZER, CARD PUNCH AND STK-1DIGITIZER

1. Turn off power.
2. Open rear access door.
3. Insert wired control panel.
4. Plug in encoder cables into appropriate sockets.
5. Set reset switches to "on" position (up).
6. Set alternate switch (underneath control panel rack) to right.
7. Turn on power (on front lower right panel).
8. Reset each display (x, y, px, py, and event counter).
9. Set count direction switches to normal (4).
10. Scale switches to X2 (4).
11. Reset alarm error.
12. Reset buffer.
13. Auto record switches to off.
14. Auto record rotary switches (4) to off.
15. RST MODE switch to 1.

CARD PUNCH

16. Turn off power.
17. Place program card on drum. Make sure edges of card are aligned with drum and tighten card on drum.
18. Place drum on spindle and engage star wheels.
19. Place AT-KB switch at AT. (Place all console switches to "on" up position).
20. Load hopper with blank cards.
21. Turn on card punch power.
22. Release two cards.

STK-1

23. Turn on power.
24. Adjust eye relief.
25. Adjust interpupillary distance.
26. Focus each eyepiece.
27. Adjust squint controls (horizontal and vertical).





The numbered columns on the card are representative of data as follows:

- zero - **card** counter - each data point has an incremented **number**
- one - **arbitrary** data for operator identification and **index** area identification
- two - **x**-coordinate of diapositive image point in **micrometers**
- three - **y**-coordinate
- four - **px** of image point in micrometers
- five - **py** of image point in micrometers
- six - **arbitrary** data for photograph identification
- seven - **arbitrary** data for area type identification ( 1 - bare **area** within gross snow area, 2 - gross snow area, **3** - total index area)
- final zero - **control** code to indicate the end of a given area (**1** - final card for a given area, 2 - final card in **the** data deck, 0 - otherwise)

The first data card to be read by the computer must be the coordinates of the principal point for each diapositive. This was usually initially set on the digitizer as 500,000 on each of the coordinates. The final card for a given data deck must have only a 2 in column 80.

A flow chart for the computer program is presented in Fig. 2.

A program listing is presented in Fig. 3.

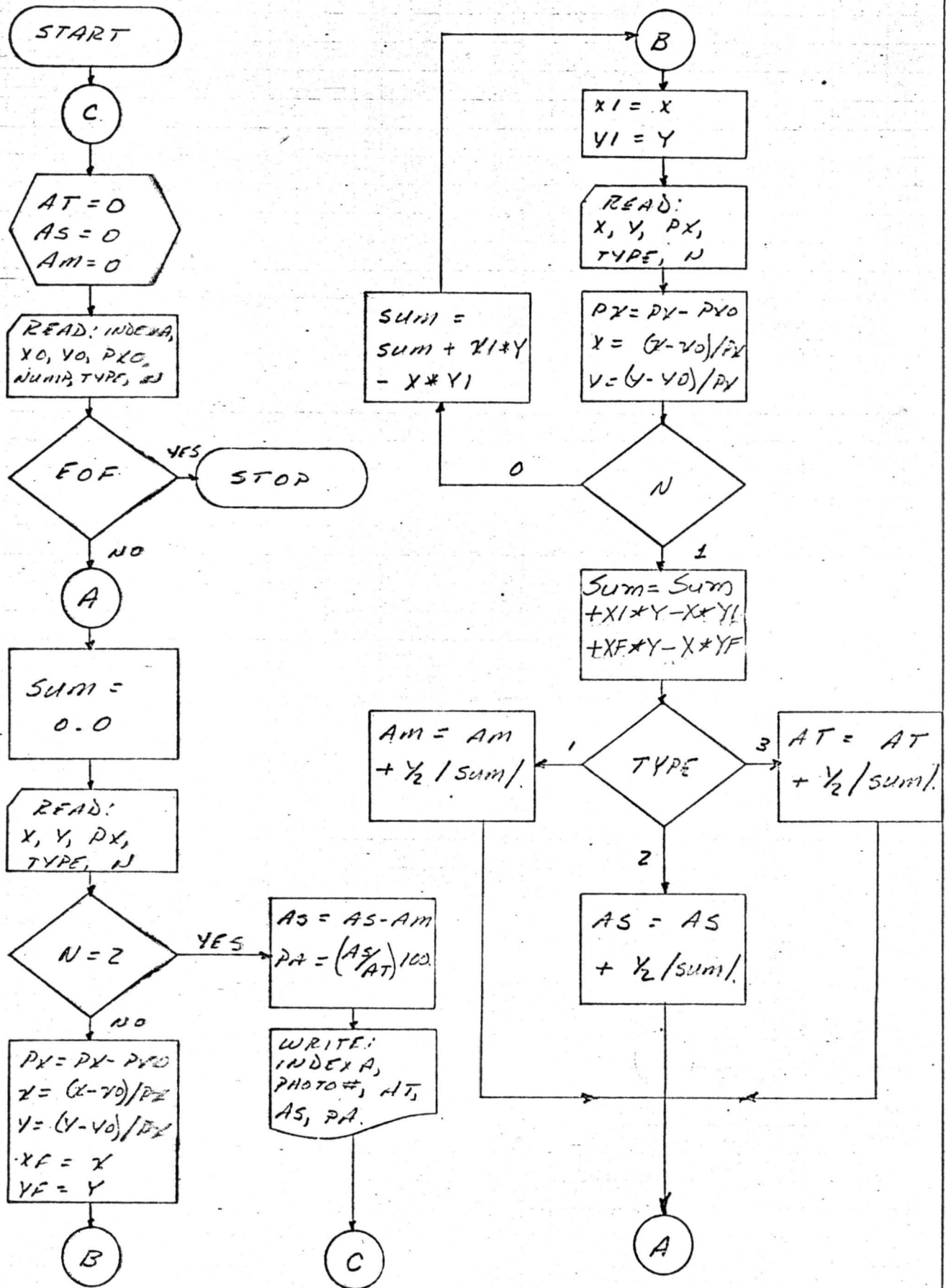


Fig. 2

INDIAN PAPERS BY Diastara  
 ENGINEERING COMPUTATION

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PROGRAM SNOW
1 (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
  INTEGER TYPE
C  AT = TOTAL AREA
C  AS = AREA OF SNOW
C  AM = AREA OF GROUND
  WRITE(6,110)
110 FORMAT(1H1,15X,*INDEX AREA*,10X,*PHOTO NUMBER*,10X,*INDEX AREA TOT
  IAL*,10X,*AREA SNOW*,10X,*SNOW COVER PERCENT*)
  10 AT = 0.0
  AS = 0.0
  AM = 0.0
  READ(5,20) INDEXA,X0,Y0,PX0,NUMP,TYPE,N
  20 FORMAT(5X,I7,3(2X,F7.0),12X,I7,I1,20X,I1)
  IF (EOF(5))120,35
120 STOP
  35 SUM = 0.0
  READ(5,20) I,X,Y,PX,L,TYPE,N
  IF (N .EQ. 2) GO TO 100
  PX = PX-PX0
  X = (X-X0)/PX
  Y = (Y-Y0)/PX
  XF = X
  YF = Y
  50 X1 = X
  Y1 = Y
  READ(5,20) I,X,Y,PX,L,TYPE,N
  PX = PX-PX0
  X = (X-X0)/PX
  Y = (Y-Y0)/PX
  IF (N) 51,51,52
  51 SUM = SUM + X1*Y - X*Y1
  GO TO 50
  52 SUM=SUM+X1*Y-X*Y1+X*YF-Y*XF
  GO TO (70,80,90),TYPE
  70 AM = AM + .5*ABS(SUM)
  GO TO 35
  80 AS = AS + .5*ABS(SUM)
  GO TO 35
  90 AT = AT + .5*ABS(SUM)
  GO TO 35
  100 AS = AS - AM
  PA = (AS/AT)*100.
  WRITE(6,130)INDEXA,NUMP,AT,AS,PA
  130 FORMAT(16X,I7,15X,I7,14X,E11.4,13X,E11.4,13X,F5.1)
  GO TO 10
END

```

```

IDENT SNOW
LIST -L,-R

```

```

000000 004052 START. LOCAL
004052 000000 VARDIM. LOCAL

```

Fig. 3

## RESULTS AND DISCUSSION

The results of 16 measurements of the index area and 14 determinations of percent of snow cover are presented in Table 3.

The index area was reproduced with a coefficient of variation (standard deviation divided by the mean value times 100) of 2.45%. The net snow area was determined with a coefficient of variation of 10.2%. The percent snow area was determined with a coefficient of variation of 9.9%.

The lower coefficient of variation for the gross area was probably due to the fact that the area was better defined and that for all but the first 4 measurements, was indicated on a photo print for the operators reference. The resultant discrepancy is probably due to measurement errors as contrasted with errors associated with delineating the desired area.

In contrast to this, the snow area determination is affected by both the operator's inherent measurement error and his judgement as to selection and description of snow areas and bare areas within the snow. Thus the coefficient is significantly larger (10.2%). This of course is reflected in the percent snow area (9.9%). The reason that the coefficient of variation of percent snow area is less than the coefficient of variation for the snow area alone is probably due to the combination of low (high) index area with low (high) snow area.

## CONCLUSIONS

The results of this limited evaluation indicate that the procedure can be used for the determination of percentage snow cover.

TABLE 3

## LEXEN CREEK INDEX AREA

DATE	OPERATOR	PHOTO-PLATE	POWER	TIME TO PUNCH CARDS (HR.)	COMPUTER TIME (SEC.)	INDEX AREA	SNOW AREA	PERCENT SNOW	CARDS FOR INDEX AREA	CARDS FOR TOTAL AREA
4-27	A.H.Barnes	Negatives	6x	2 1/2	2.574	.3246	.1110	34.2	46	645
4-30	A.Haeffner	"	"		0.482	.3409	--	--	125	--
5-1	R.Dvorak	"	"	5	2.728	.3401	.1085	31.9	68	655
5-7	R.Dvorak	"	"	3 1/2	1.847	.3455	.1280	37.0	57	459
5-13	R.Dvorak	Positives	"	3 1/2	0.269	.3228	--	--	67	--
5-17	R.Dvorak	"	"	4	} 3.232	.3212	.1162	36.2	71	463
5-17	R.Dvorak	"	"	3		.3244	.1137	35.0	74	362
5-20	B.Brier	"	"	2	1.011	.3319	.1600	48.2	71	252
5-21	B.Brier	"	"	1 1/2	1.261	.3287	.1267	38.6	69	311
5-23	R.Dvorak	"	"	3	} 2.910	.3217	.1153	35.8	72	360
5-24	R.Dvorak	"	"	3		.3204	.1184	37.0	71	352
5-25	A.Haeffner	"	"		5.286	.3209	.1277	39.8	71	1320
5-27	A.Haeffner	"	"		5.637	.3222	.1261	39.1	71	1412
5-28	A.Haeffner	"	11x		6.041	.3244	.1245	38.4	71	1528
5-31	R.Dvorak	"	"	2 1/2		.3230	.1198	37.1	72	413
6-11	A.H.Barnes	"	"	2 1/2		.3230	.1273	39.4	88	530
Mean						.32723	.12308	37.69		
Std. Dev.						± .0080	± .01252	± 3.73		
Coef. of Var.						2.45%	10.2%	9.9%		

The procedure involves a minimum number of opportunities for operator mistakes or blunders. The computational procedure is entirely computer oriented and hence not subject to human error.

No attempt was made to evaluate this procedure with other methods in use. These comparisons were considered outside the scope of this study.

### RECOMMENDATIONS

The accuracy and precision of the procedure could be improved by consideration of several additional factors. These factors affect either the operator or the computations.

Improvement of the operator factors would include;

- 1) Improving the quality of the photographic printing of the diapositives -- By commercially available controlled contrast printing, the extreme contrast between snow, ground, shadows, trees, rocks, etc. could be reduced and hence better identification of the snow areas would result.
- 2) Delineation of snow areas -- Identification of the individual snow and bare areas to be computed would eliminate a judgment decision by the operator. This identification could be made on an enlargement of as much as 4 to 6 magnification.

Improvement of the photogrammetric factors would include:

- 1) Ground control -- Identifiable targets of known position on the ground would permit the recovery of the complete orientation of the camera at the time of exposure. This would eliminate the need for the assumptions of vertical photographs, and equal altitudes of exposure.

- 2) In lieu of ground control, it may be possible to partially compensate for tilt and elevation by using the level bubble and altimeter on each exposure. Although this is far from precise, it would be a reasonable second approximation to camera orientations.