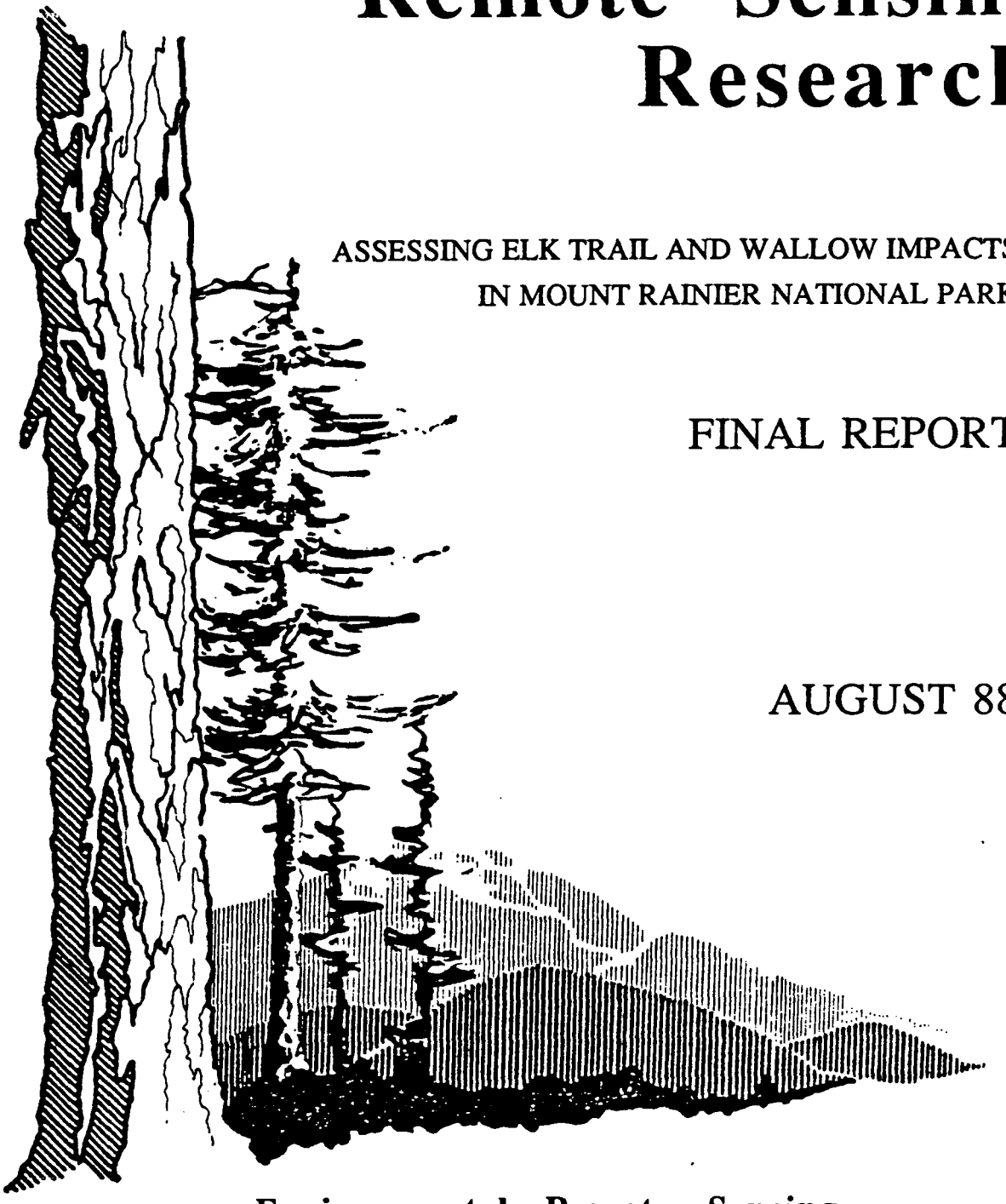
Remote Sensing Research



ASSESSING ELK TRAIL AND WALLOW IMPACTS IN MOUNT RAINIER NATIONAL PARK

FINAL REPORT

AUGUST 88

Environmental Remote Sensing Applications Laboratory - ERSAL

OREGON STATE UNIVERSITY
COLLEGE OF FORESTRY

ASSESSING ELK TRAIL AND WALLOW IMPACTS IN MOUNT RAINIER NATIONAL PARK

FINAL REPORT

Submitted to

The National Park Service
Cooperative Agreement CA-9000-3-0003
SubAgreement 16

Submitted by

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ASSESSING ELK TRAIL AND WALLOW IMPACTS IN MOUNT RAINIER NATIONAL PARK

I. INTRODUCTION AND OBJECTIVES

There is concern that the apparent population growth of Mount Rainier's north elk herd may be subjecting several park ecosystems to overuse, damage and substantial alteration. Therefore, the purpose of this project was to develop a system to inventory and monitor trails and wallows caused by elk in the northeastern part of Mount Rainier National Park. The objectives of this three year project as outlined in subagreement 16 to cooperative agreement CA-9000-3-0003 between Oregon State University and the National Park Service include:

1. Development of a remote sensing system to monitor the onset/or rapid change in elk trailing impacts using aerial photography

2. Enumeration and mapping of elk trails and the estimation of the area of exposed soil associated with these trails.

3. Establishment of an inventory and monitoring system for documenting elk wallow areas.

Natural color aerial photography was obtained in 1985, 1986, and 1987. The scale of the photographs range from 1:5,000 to 1:6,000. The flight dates were August 6 and 12, 1985 (185 photos), August 14 and

September 9, 1986 (154 photos), and August 4, 1987 (36 photos). Aerial survey flight maps for each year can be found in appendix I. This aerial photography was used to both develop an elk impact monitoring system and establish baseline data. A number of approaches were developed to meet the above objectives using a combination of aerial photo interpretation and field work. These approaches are described in the following text with sections entitled: II Field Enumeration and Mapping, III Elk Wallow Inventory, IV Preliminary Interpretation and Accuracy Assessment, V Permanent Photo Plots, VI Systematic Sampling for Elk Trails, and VII Methods for the Acquisition and Interpretation of Aerial Photography.

II. FIELD ENUMERATION AND MAPPING

Methods were developed to map and quantify elk trail impacts in **areas covered partially by forest canopies**. This elk trail enumeration and mapping is sensitive to both the number and location of trails. This procedure identifies elk trails and provides statistics showing the areal extent of vegetation loss due to elk trails.

Methods

The methods involved enlarging Park resource aerial photography from a scale of 1:24,000 to a scale of 1:6,000. Topographic contour lines and stream locations were transferred from 7.5' topographic quadrangles to clear overlays on the enlarged photography. The mapping of elk trails was conducted in the field using the topographic overlays on the photographic

enlargements. Sites selected for trail enumeration were completely canvassed by hiking each enumeration area. All elk trails that were discovered in enumeration areas were delineated on the photo enlargements. Oblique 35mm photographs were acquired from the end of each trail. Trail width measurements were taken at points five meters from the ends of each trail and at the point approximately midway between the two ends of each trail. The line intercept method was used to record the extent of any green vegetation that intercepted the tape measure as it was laid across each trail for the width measurements. The enumeration areas were located in areas with significant elk impacts and in areas with little or no present impacts. These areas included sites at both Lower and Upper Huckleberry Basin, sites near Sunrise Lake and Clover Lake, and a site in Bear Park.

Results

Table 1 shows the average width of trails found in each of the five enumeration areas. The overall mean trail width was 0.43m with an average green vegetation width (intercept) of 0.04m. Table 2 illustrates the extent of elk trails and the amount of bare soil exposed in each of the enumeration areas. The extent of elk trails (m/km^2) was determined by dividing the total length (m) of trails in an area by the size of the area (km^2). The length of trails were determined with the aid of an electronic digitizer tablet. The amount of bare soil (m^2/km^2) in each enumeration area was calculated by dividing the area of exposed bare soil (m^2) by the size of the enumeration area (km^2). Table 2 shows that the trail impacts

were highest at the Lower Huckleberry Basin and Clover Lake and lowest at the Upper Huckleberry Basin and Sunrise Lake enumeration areas. Appendix II contains listings of all trail measurements and copies of the trail maps for each of the five areas.

TABLE 1. AVERAGE ELK TRAIL WIDTH AND AMOUNT OF BARE SOIL FOUND ON TRAILS IN FIVE ENUMERATION AREAS.

Enumeration Area	Average Trail Width (M)	Average Vegetation Width (M)	Average Bare Soil Width (M)
Upper Huckleberry Basin	--	--	--
Sunrise Lake	.41	.07	.34
Bear Park	.46	.05	.41
Clover Lake	.38	.04	.34
Lower Huckleberry Basin	.45	.03	.42
Overall Average	.43	.04	.38

TABLE 2. EXTENT OF ELK TRAILS AND AMOUNT OF BARE SOIL EXPOSED IN FIVE ENUMERATION AREAS.

Enumeration Area	Size of Area (Km^2)	Extent of Elk Trails (M/Km^2)	Amount of Bare Soil (M^2/Km^2)
Upper Huckleberry Basin	.068245	-0-	-0-
Sunrise Lake	.105548	1,568	508
Bear Park	.075807	6,575	2,687
Clover Lake	.166856	13,007	4,564
Lower Huckleberry Basin	.104175	14,502	6,329

III. ELK WALLOW INVENTORY

Methods

An inventory was conducted to identify critical areas for elk trail trampling and wallowing. A critical area was defined as a site in a wet meadow having bowl-shaped depressions or showing evidence of trampling. Trampling activity was characterized by a loss of vegetation, while the bowl-shaped depressions were identified as features used by elk for wallowing. All of the 185 aerial photographs that were acquired in August of 1985 were examined for critical areas.

Results

Twenty-three critical areas were identified on the aerial photography. A black arrow was placed adjacent to each critical area on the aerial photographs. These locations were transferred to 7.5' quadrangle maps to illustrate the location and the index number of each critical area (Figure 1.). The description and location of each critical area can also be found in Table 3.

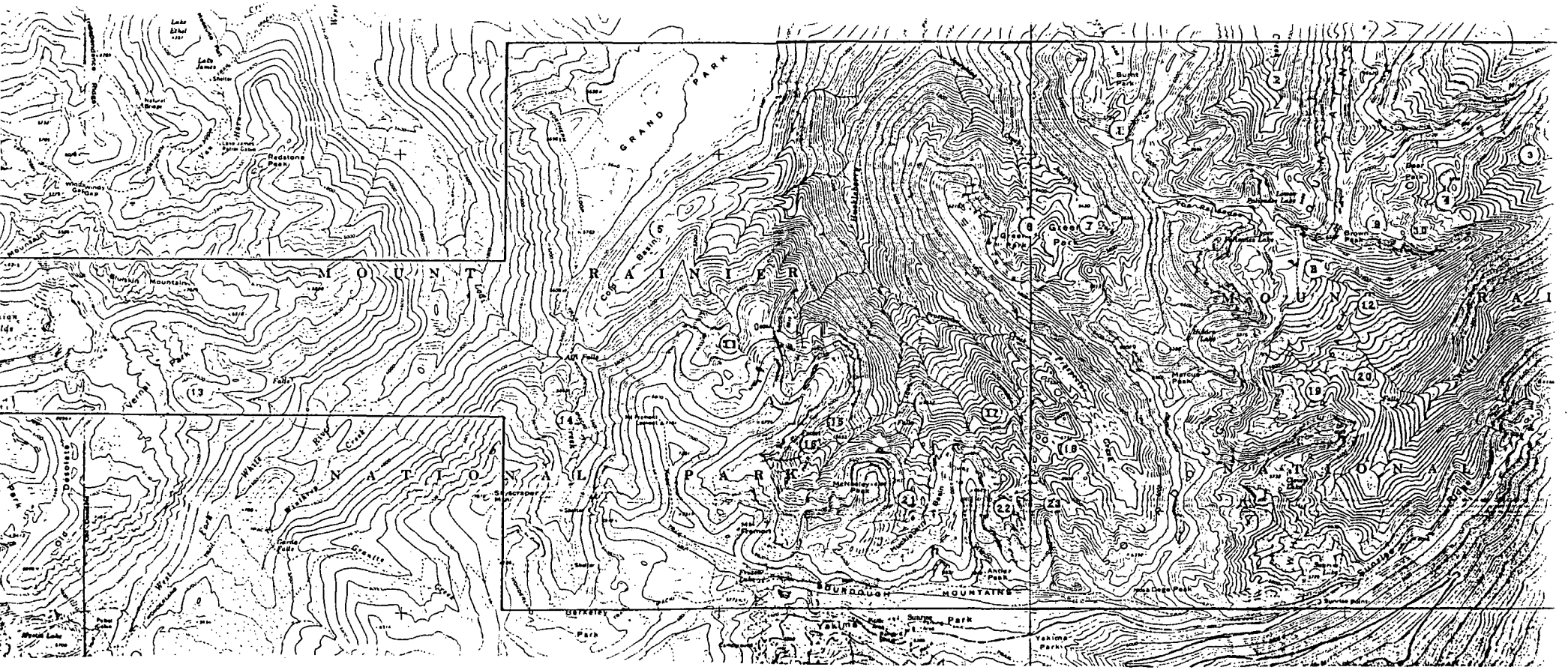


Figure 1. Location of twenty-three (23) critical areas for Elk trampling and wallowing.

Table 3.

MOUNT RAINIER NATIONAL PARK
CRITICAL AREAS: ELK TRAMPLING AND WALLOWING - 1985

Map Index Number	Photo Number	Ground Photo Number	Description
1	1-11	-	Bare soil areas adjacent to Lake
2	1-15	-	Bare soil areas along stream in small open area
3	1-19	-	Bare soil areas along with depressions in small open area
4	2-21	4a - 4g	Depressions in meadow near Lake
5	3-02	-	Depressions found throughout Cold Basin
6	3-11	-	Depressions in meadow opening
7	3-11	-	Depressions near Lake
8	3-16	8a	Large bare soil area and depressions near Brown Peak
9	3-20	9a - 9c	Depressions just west of Bear Lake
10	3-20	-	Wet bare soil area east of Bear Lake
11	4-16	-	Depressions in meadow near stream
12	4-29	-	Wet depressions in very small forest opening
13	5-07	-	Depressions scattered throughout Vernal Park
14	5-15	-	Brownish area near stream in meadow
15	5-22	-	Depressions in small opening just northeast of Lake
16	5-22	-	One depression on meadow edge southwest of Lake
17	5-24	-	Depression in very small forest opening
18	5-26	-	Small depression near stream southeast of Lake
19	5-32	-	Depressions and bare soil areas in meadow at photo center
20	5-32	-	Wet depression in small forest opening
21	6-08	21a - 21c	Two depressions and bare soil areas in Huckleberry Meadow
22	6-11	-	Two depressions along stream near small Lake
23	6-12	-	Two depressions along stream

IV. PRELIMINARY INTERPRETATION AND ACCURACY ASSESSMENT

Methods

185 natural color aerial photographs were obtained from flights on August 6 and August 12, 1985. The flight lines were located over a selected area in a region extending from Elysian Fields to Bear Park. The contact scale of the 9" x 9" color negatives was approximately 1:6,000.

Standard aerial photographic interpretation methods were used to delineate elk trails in four non-forested areas selected for preliminary analysis, each with a different slope aspect. The photographic interpretation and mapping work was performed in the laboratory on enlarged prints at a scale of 1:2,400.

Field checking for elk trail mapping accuracy was accomplished in September of 1985. The preliminary interpretation overlays of delineated trails were removed from the enlargements before the field trip. The field checking consisted of a complete canvassing of each of the four areas. All trials were delineated on photographs in the field for each area using methods described in the elk trial enumeration and mapping section of this paper. An accuracy assessment was conducted by comparing the results of the laboratory mapping to the results of the field mapping.

Results

Table 4 contains the results of the accuracy assessment. Overall, the results ranged from 61.0% of the trails interpreted correctly on Green Park Ridge to a high of 95.8% at the Bear Park East site. The ridge sites resulted in the lowest accuracies due to a lack of contrast between non-vegetated trails and slopes with drying vegetative cover. Since the 1985 season was very dry, the color of the herbaceous vegetation was brown instead of green on the aerial photography. This resulted in little contrast between the vegetation and the elk trails, causing mostly omission errors on the ridges and other dry areas. The average trail width ranged from 40 cm at the Bear Park East site to 59 cm on Bear Park Ridge. Appendix III contains maps which can be used to compare the photo interpretation of the elk trails with the ground truth.

Table 4. Remote Sensing Mapping Accuracy of Elk Trail Mapping at Four Sites in Mount Rainier National Park

Location	Aspect	Percent Correct	Average Trail Width
Bear Park North	North	92.4%	43 cm
Bear Park East	East	95.8%	40 cm
Bear Park Ridge	West	64.8%	59 cm
Green Park Ridge	South	61.0%	52 cm

V. PERMANENT PHOTO PLOTS

Methods

Baseline data on elk trails were established for ten photo plots on the 1986 aerial photography and six corresponding photo plots on the 1985 aerial photography. These square photo plots were selected by Mount Rainier National Park staff to serve as permanent sites for the elk trail monitoring system. Table 5 shows the photography frame numbers associated with these selected sites. Only sites that appeared to have favorable elk habitat and were relatively free from large areas of closed forest canopy were chosen. Sites near the edges of photographs were avoided because of radial displacement problems associated with photographic edges. Elk trails were delineated inside each photo plot with a fine point black ink pen on clear acetate.

Table 5. Locations and frame numbers associated with the photo-plot sampling sites selected by Mount Rainier National Park Staff.

	1986	1985
Fremont Lookout North	7E-4	4-16
Green Park	6E-5	3-10
Burnt Park	4E-3	1-11
Vernal Park	8W-6	5-7
Elysian Fields West	7E-3	4-1
Bear Park	5E-13	3-19
Sluiskin Mountain	6W-7	
Fawn Ridge	1-8	
Slide Mountain	3-6	
No Name Park	3-2	

Field work for ground data collection was conducted in August, 1986 and August, 1987 in the Fremont Basin photo plot. Oblique 35 mm photographs

were acquired for each elk trail at approximately the same location each year. Trail width measurements were taken at points five meters from the ends of each trail and at the approximate midway point between the ends of each trail. The line intercept method was used to record the extent of any vegetation that intercepted the tape measure as it lay across each trail. A new technique was developed to obtain vertical photographs of a portion of the elk trails. This technique consists of extending a monopod over and normal to the tape as it lay across the trail. The photographs were exposed at a height of approximately two meters above the trail.

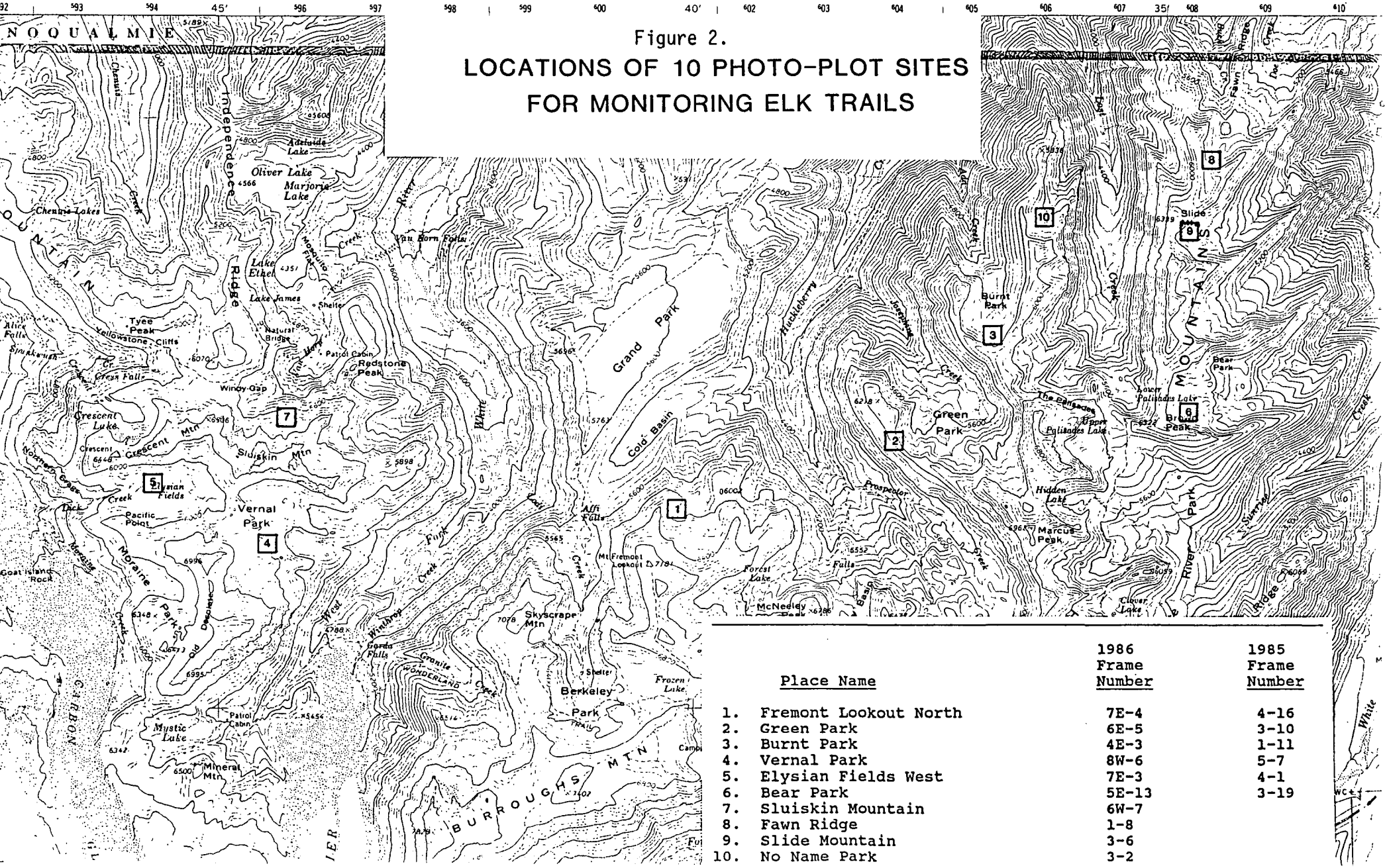
Results

Figure 2 shows the locations of the ten permanent photo plots, and Appendix IV contains images-maps showing the trails delineated for each photo plot. From August 1985 to August 1986 there appeared to be no detectable increase in elk trails in the Bear Park plot. The Elysian Fields West plot also had no detectable increase and appeared to be free from trails during both years. The interpretation results for Green, Burnt, and Vernal Park plots show slight increases in the extent of elk trails from 1985 to 1986. There appeared to be a significant one year increase in elk trails for the Fremont Basin plot between 1985 and 1986. It should be noted that a portion of the trail differences on these sets of aerial photographs could be the result of differences in photo quality, distance from the photo centers, and plant phenological stages.

MT. RAINIER NATIONAL PARK

Figure 2.

LOCATIONS OF 10 PHOTO-PLOT SITES FOR MONITORING ELK TRAILS



	Place Name	1986 Frame Number	1985 Frame Number
1.	Fremont Lookout North	7E-4	4-16
2.	Green Park	6E-5	3-10
3.	Burnt Park	4E-3	1-11
4.	Vernal Park	8W-6	5-7
5.	Elysian Fields West	7E-3	4-1
6.	Bear Park	5E-13	3-19
7.	Sluiskin Mountain	6W-7	
8.	Fawn Ridge	1-8	
9.	Slide Mountain	3-6	
10.	No Name Park	3-2	

The results of the August 1986 and August 1987 trail measurements in the Fremont Basin photo plot indicate continued intensive use of existing trails, rather than the development of additional elk trails. In 1986, the mean trail width was 56.5 cm, with a mean vegetation width (intercept) of 9.0cm. In 1987, the mean trail width increased to 58.8 cm, while the mean vegetation width (intercept) decreased to 6.2 cm. The ground photographs of these elk trails also show an increase of bare soil on some of the trails in the photo-plot. Appendix V presents the data relating to the trail measurements obtained in the 1986 and 1987 field season.

Aerial photography was also obtained in 1987 for Vernal Park, Elysian Fields, and Sluiskin Mountain. No changes in elk impacts were discovered for these photo plots.

VI. SYSTEMATIC SAMPLING FOR ELK TRAILS

The aerial photography from both 1985 and 1986 was used to conduct a survey of elk trails within the project area in the northeast part of Mount Rainier National Park. The objectives were 1) to obtain baseline data on the extent of elk trials, and 2) to show relative differences in elk trail impacts by geographic area.

Methods

A quantification of elk trails visibly present on the aerial photography was obtained by placing a two-by-two grid centered on the principal point of every other photograph for every flight line (Figure 3). The dimension of each grid cell was 6cm by 6cm. The presence, or absence, of visible elk trails was determined for each of the four grid cells on the photographs (Appendix VI). An ocular estimate of percent forest canopy cover was also recorded for each grid cell. Presence values for each of the sampled photographs ranged from "0" through "4" -- a value of "0" indicated elk trails were visibly absent from all cells, while a value of "4" indicated the visible presence of elk trails in all four grid cells per photograph.

Results

The results from the 1985 photography indicate a relatively low presence of elk trails at Grand Park, Cold Basin, and Elysian Fields (Figure 4). Few elk trails were found near human developments, such as Sunrise Road and

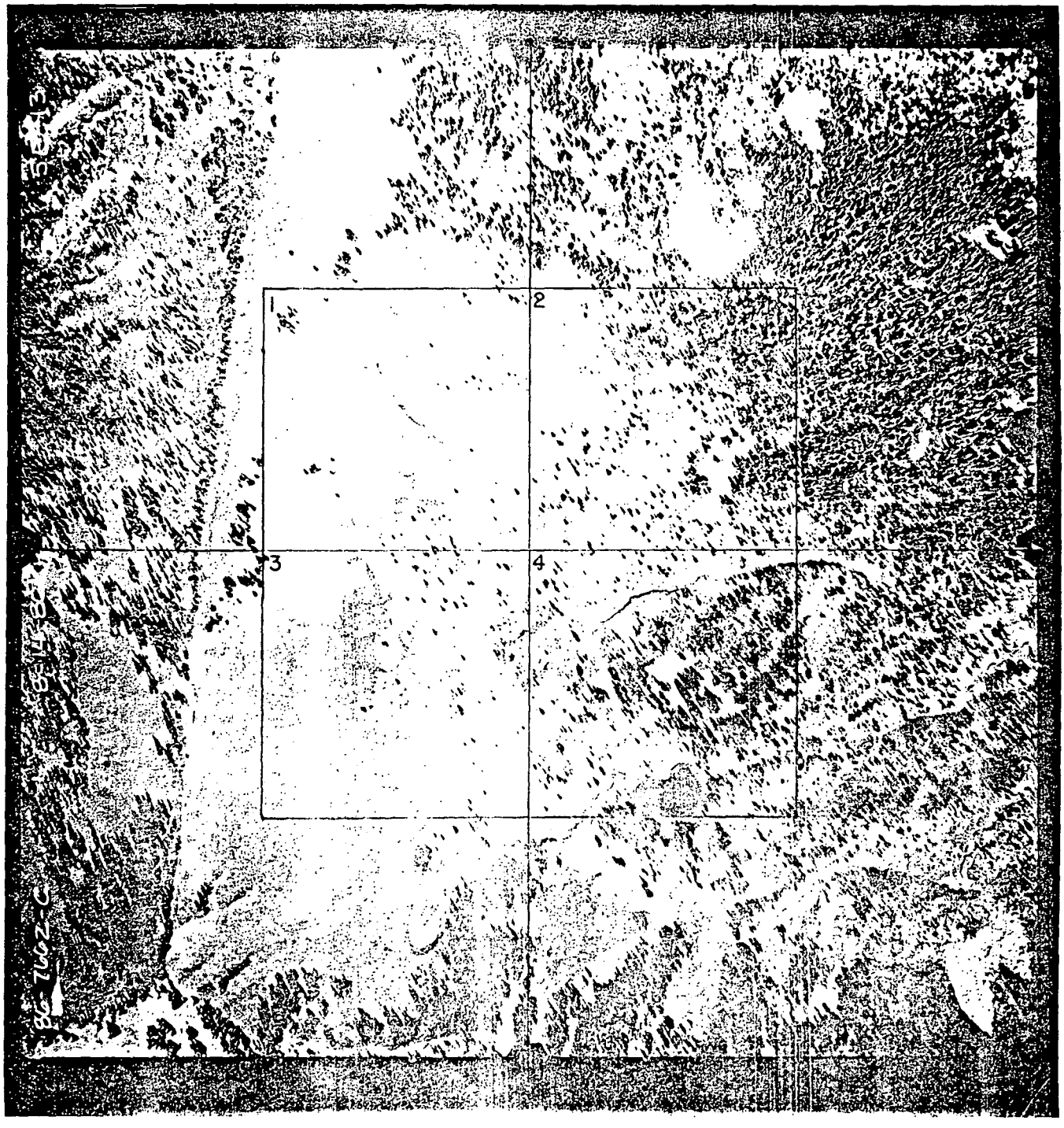


Figure 3. Example of grid used to quantify the presence of elk trails using the aerial photography from 1985 and 1986.

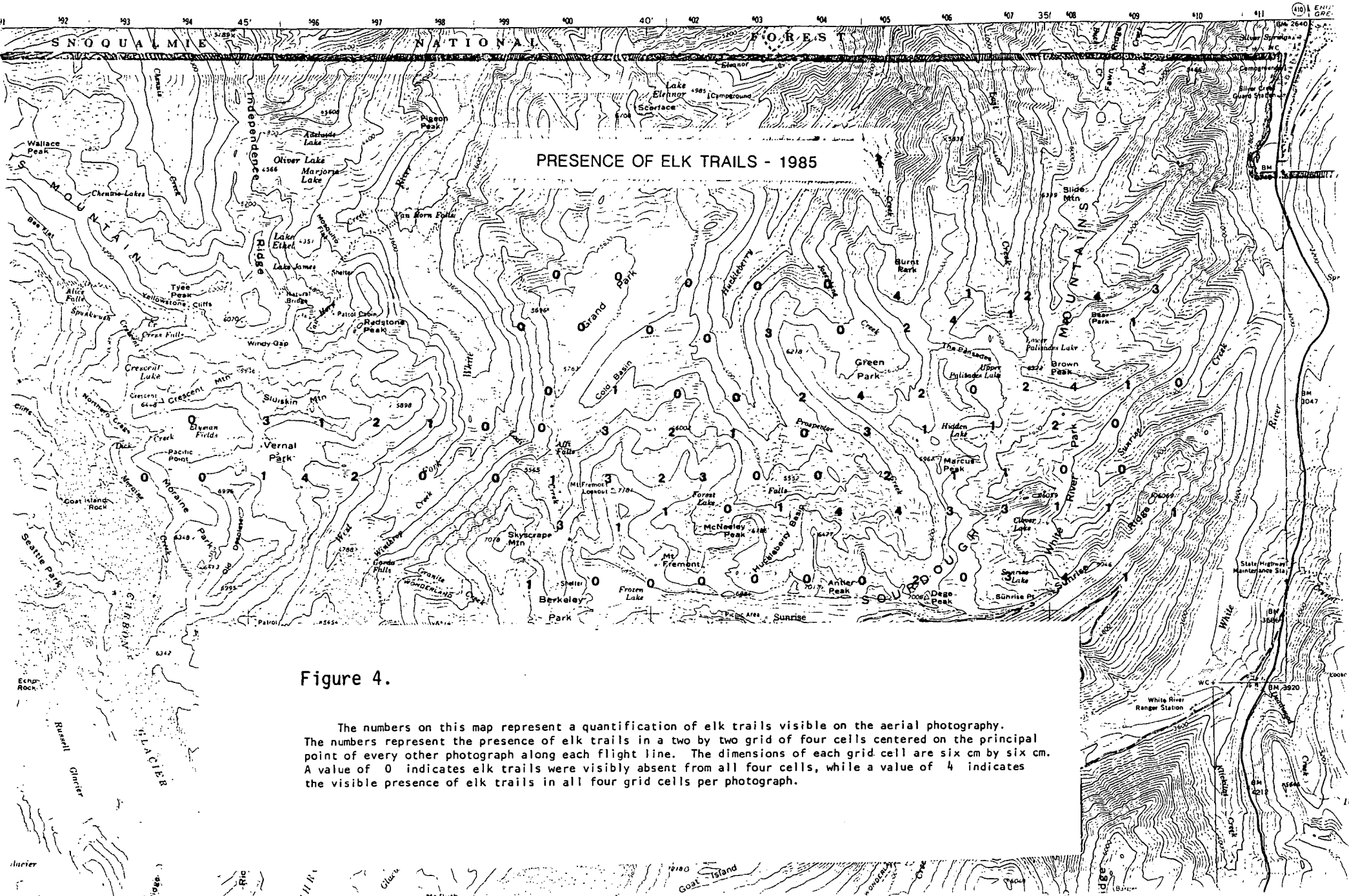


Figure 4.

The numbers on this map represent a quantification of elk trails visible on the aerial photography. The numbers represent the presence of elk trails in a two by two grid of four cells centered on the principal point of every other photograph along each flight line. The dimensions of each grid cell are six cm by six cm. A value of 0 indicates elk trails were visibly absent from all four cells, while a value of 4 indicates the visible presence of elk trails in all four grid cells per photograph.

the Sunrise Ranger Station. Numerous elk trails were seen at Bear Park, Brown Peak, Burn Park, Green Park Ridge, Fremont Lookout, Vernal Park, and the area north of the Sourdough Mountains (Figure 4).

Compilation results from the 1986 aerial photography indicate a significantly high level of elk trails in the area between Bear Park and Fawn Ridge, including the Slide Mountain area (Figure 5). Numerous elk trails were also found in the Tyee Peak, Windy Gap, and Sluiskin Mountain areas.

The frequency of elk trails were also displayed in relation to percent forest canopy cover for both the 1985 and 1986 aerial photography (Figure 6). The visible presence of elk trails was highest in areas with substantial patches of both hiding/thermal cover (forested areas) and forage habitat (open areas). On the 1985 photography, visible trails were most frequent in areas of 65, 30, and 35/40 percent forest canopy cover. The 1986 photography showed elk trail frequencies highest at sites of 40, 30, and 50 percent canopy cover. It should be noted that it was not possible to estimate the quantity of elk trails below tree canopies from the aerial photography, and forest canopy coverage of greater than 90 percent obscured nearly all elk trails.

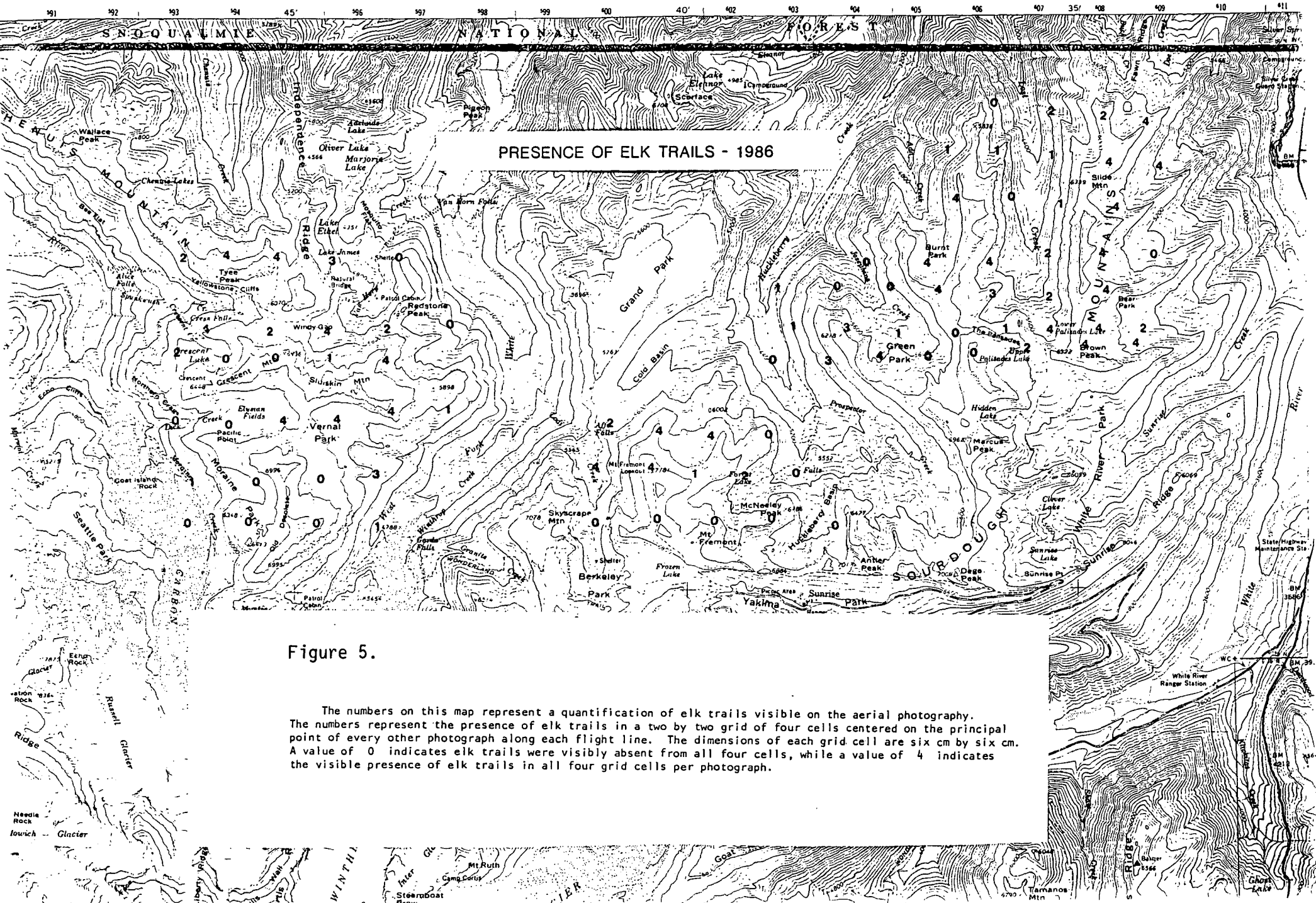


Figure 5.

The numbers on this map represent a quantification of elk trails visible on the aerial photography. The numbers represent the presence of elk trails in a two by two grid of four cells centered on the principal point of every other photograph along each flight line. The dimensions of each grid cell are six cm by six cm. A value of 0 indicates elk trails were visibly absent from all four cells, while a value of 4 indicates the visible presence of elk trails in all four grid cells per photograph.

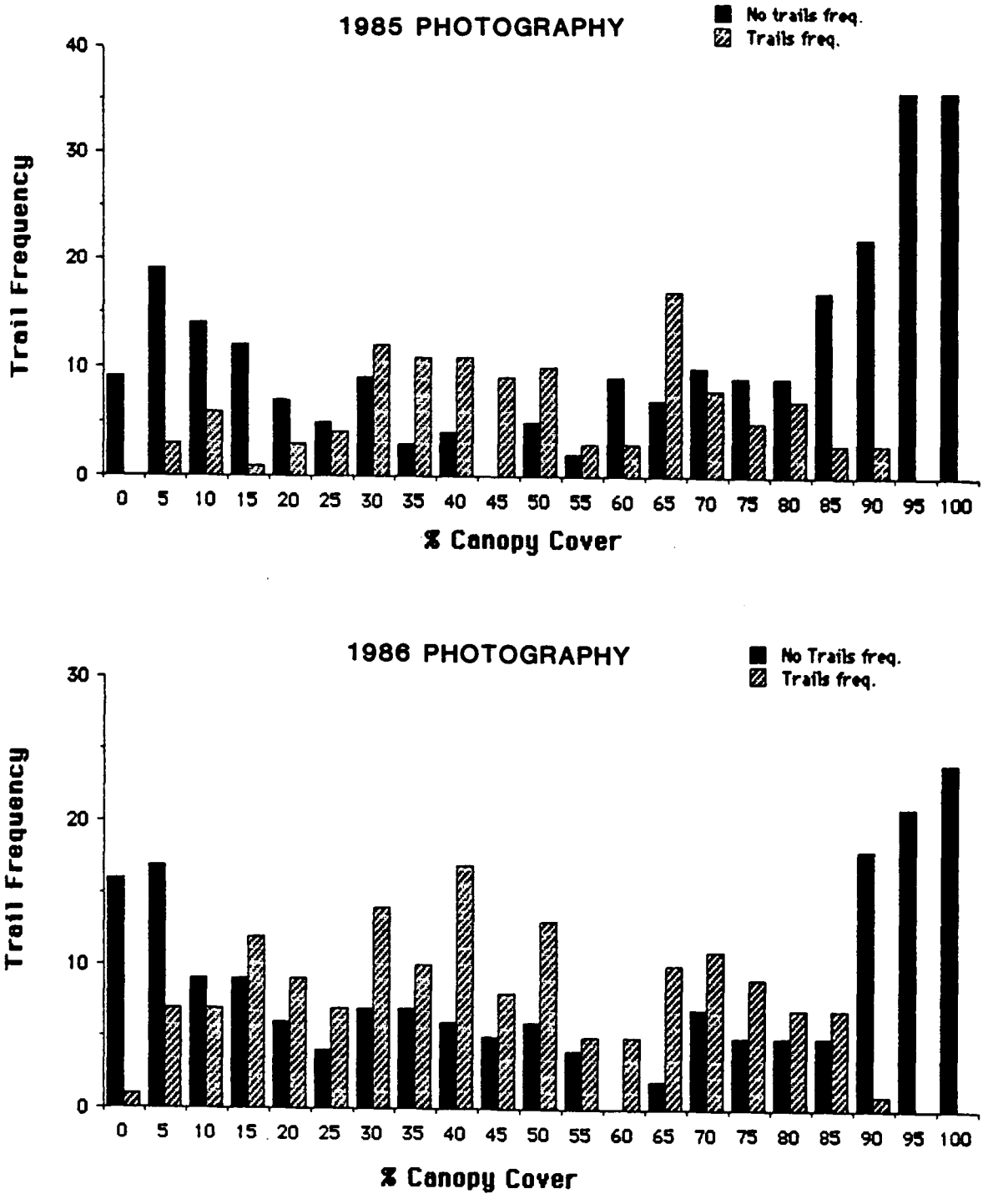


Figure 6. Bar graphs showing percent forest canopy cover on the x-axis, and on the y-axis, the frequency of trails both observed and not observed within the grid cells.

VII. METHODS FOR THE ACQUISITION AND INTERPRETATION OF AERIAL PHOTOGRAPHY

INTRODUCTION

The objective of this section is to describe in detail the procedures used and the techniques required to obtain new aerial photography for the detection of elk impacts in the sub-alpine zone of Mount Rainier National Park. This discussion is based on several years experience in the use of low altitude aerial photography for the interpretation of elk impacts.

FLIGHT PLANNING

If existing aerial photography is not suitable for the application at hand, it may be necessary to contract for new aerial photography. The photo interpreter will then need to be responsible for determining the project objectives, producing a flight plan, and inspecting the newly acquired aerial photography. To accomplish this, the interpreter must become familiar with aerial photography specifications.

Scale of Aerial Photography

The scale of the aerial photography should be one of the first considerations in the planning phase. The scale needs to be large enough and show enough detail to meet the objectives of the project. For the

Mount Rainier elk impact study, we used 2.5X enlargements of the 1:5,000 scale contact prints for mapping elk trails.

The photographic scale is determined by the altitude of the aircraft and the focal length of the camera lens where:

$$\text{Photographic Scale} = \frac{\text{Camera Focal Length}}{\text{Altitude above ground datum}}$$

For example, we used a one-foot (12") focal length lens and a 5,000 foot altitude above the ground. This resulted in approximately 1:5,000 nominal scale on flat terrain. In rugged terrain, a decrease in ground elevation causes a smaller scale, while an increase in ground elevation results in a larger scale. For the Mount Rainier project, the pilot would determine the altitude of the plane independently for each flight line based on the average elevation of each flight line. For cost efficiency, it is best to specify the smallest scale that will meet the project requirements. A doubling of the photographic scale will require a four-fold increase in the number of frames needed to cover the same area.

Season and Time of Day

The season for scheduling a photographic mission at Mount Rainier will be dependent upon the objectives of the project, the amount of snow cover, the sun angle required, and plant phenology. For vegetation and soils analysis, it is generally recommended that the photography be acquired during the plant growing season, with a high sun angle, and after the seasonal snow melt.

The time of day is a very important flight specification. With vegetation analysis, the flight should be within two hours of solar noon to provide maximum reflectance from low reflecting plant canopies. The elk impact photography was exposed approximately from 9:53 a.m. to 10:30 a.m. in 1985, 10:37 a.m. to 11:55 a.m. in 1986, and 10:23 a.m. to 10:52 a.m. in 1987. With variability in the time of the exposures, there is variability in the direction and length of the shadows cast by the trees.

Specifications of the Aerial Photography

The following specifications have been suggested by Avery (1977):

Business arrangements -- These include the cost of the aerial survey, the assumption of risks and damages, a provision for the inspection of work, reflight, cancellation privileges, schedules for delivery, payments, and ownership of negatives.

Area to be photographed -- This should include a flight map that shows the location, size, and boundaries of the study area.

Type of film -- Natural color, color infrared, or black and white film may be specified. Film positives or film negatives may also be options.

Flight line position -- Flight lines are normally parallel to the long dimension of the study area, and in either an east-west or a north-south direction.

Overlap -- The overlap is usually set to an average of 60 percent along the line of flight and 30 percent between adjacent lines. At the ends of each flight line, the two photo centers should fall just outside the study area boundary. For difficult mountainous terrain, such as in Mount Rainier National Park, it is recommended that a 45 percent sidelap be used to assure complete photographic coverage.

Print alignment (crab and drift) -- Crab is indicated when the sides of the photographs are not parallel to longitudinal track of the plane. Drift occurs when the exposures are made while the airplane has drifted from the predetermined flight line. Crab and drift should not affect more than 10 percent of the print width of any three consecutive photographs.

Time of photography -- Both a range of dates and the preferred time of day for the exposures are specified.

Materials to be delivered -- Usually the negatives (or transparencies) and a set of contact prints are supplied. A copy of the original flight map may also be requested.

Inspection of aerial photography -- Photographic frames should be dated in the upper left corner, while project, roll, and frame numbers should be in the upper right corner of the exposure. Altitude or scale and local time are normally placed at the top of the first and last exposures of a flight line. The inspection of the aerial photography usually involves checking for tilting, scale, overlap, and image quality.

Flight plan -- Flight plan specifications and a preliminary flight map are required before the flight. The flight plan used for constructing the 1985 flight map for the Mount Rainier project is shown in appendix VII. These variables were computed according to the procedures suggested by Avery (1977). Avery's procedural steps are also shown in appendix VII.

Aerial survey firms & film processors -- A directory of aerial photography service companies and aerial film processing companies for black and white, color, and color infrared films can be found in appendix VIII.

STEPS FOR PHOTOINTERPRETATION OF ELK TRAILS

1. Make enlargements (2.5X) of the areas of the areas of interest from the original 9X9 inch negatives (1:5,000 scale).

2. Place clear mylar over the enlargements and tape the mylar to the photographs with drafting tape.

3. Place registration marks on the mylar.

4. Delineate elk trails with a fine point ("00" or a "000") technical ink pen.

5. Field check the resulting elk trail map for accuracy.

6. Correct any omission or commission errors that are found on the map. Omission errors occur when the vegetation is brown, resulting in little contrast between the trail and the adjacent vegetation. It should also be noted that tree shadows obscure the elk trails on the photography. Commission errors occur when down and decaying logs are interpreted as elk trails.

VIII. RECOMMENDATIONS

An elk impact monitoring system has been established for Mount Rainier National Park. This system uses a combination of large scale aerial photography and field work. The elk trail monitoring system is designed for the collection of detailed data in nonforested areas using aerial photographic interpretation techniques and for the collection of detailed data in forested areas using field enumeration and mapping methods. Regional level monitoring is accomplished through systematic sampling for elk trails using the entire set of aerial photography by recording the visible presence of elk trails within grid cells. A method for the inspection of critical elk wallow areas has been suggested. The first baseline data were collected using 1985 aerial photography.

It is recommended that new aerial photography be acquired at least every five years to provide data on elk impact changes. If new photography is obtained by 1990, a change analysis should be conducted using the detailed photo plots, the general systematic sampling method, and the inspection for critical elk wallow areas. Field enumeration and mapping in forested areas can be accomplished at any time since this approach does not require new aerial photographs. It is recommended that the existing field enumeration overlays be updated by 1990.

REFERENCES

Avery, E.T. 1977. Interpretation of Aerial Photographs. Burgess Publishing Company, Minneapolis, Minnesota. 392 p.

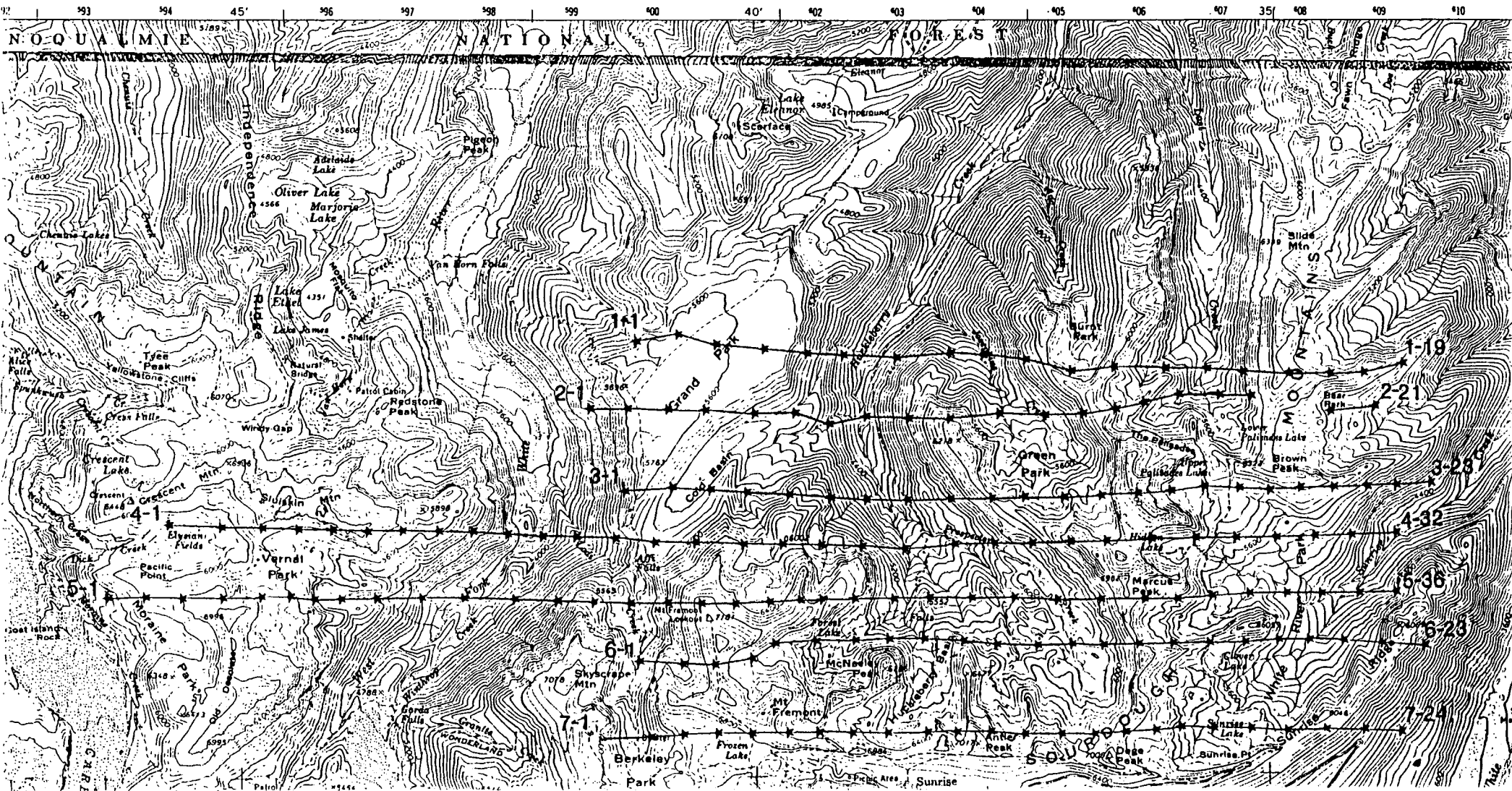
APPENDIX I

Aerial Survey flight Maps

ELK IMPACTS STUDY

AUGUST 6 & 12, 1985 AERIAL PHOTOGRAPHY

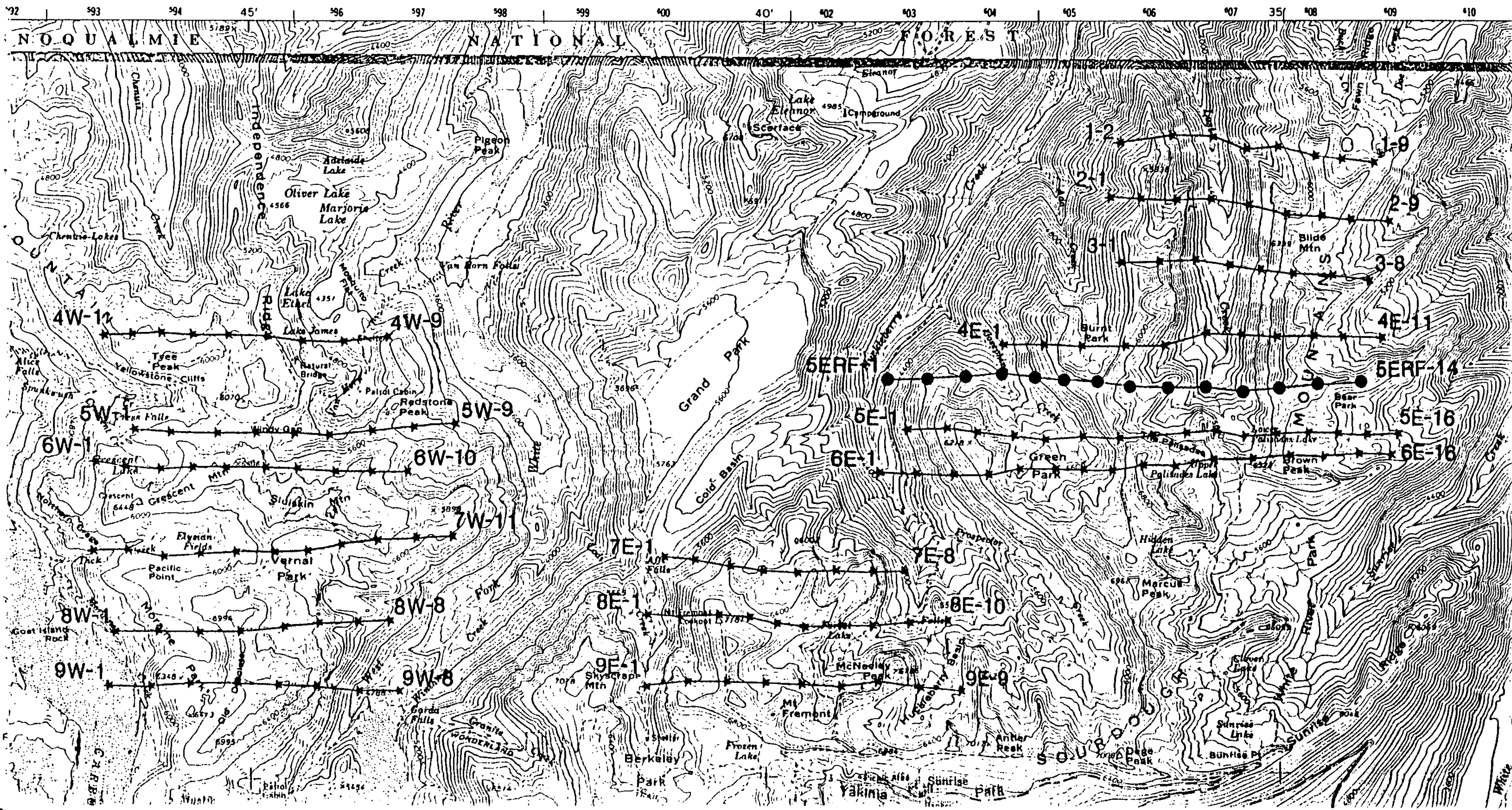
MT. RAINIER NATIONAL PARK



ELK IMPACTS STUDY

AUGUST 14 & SEPTEMBER 9, 1986 AERIAL PHOTOGRAPHY

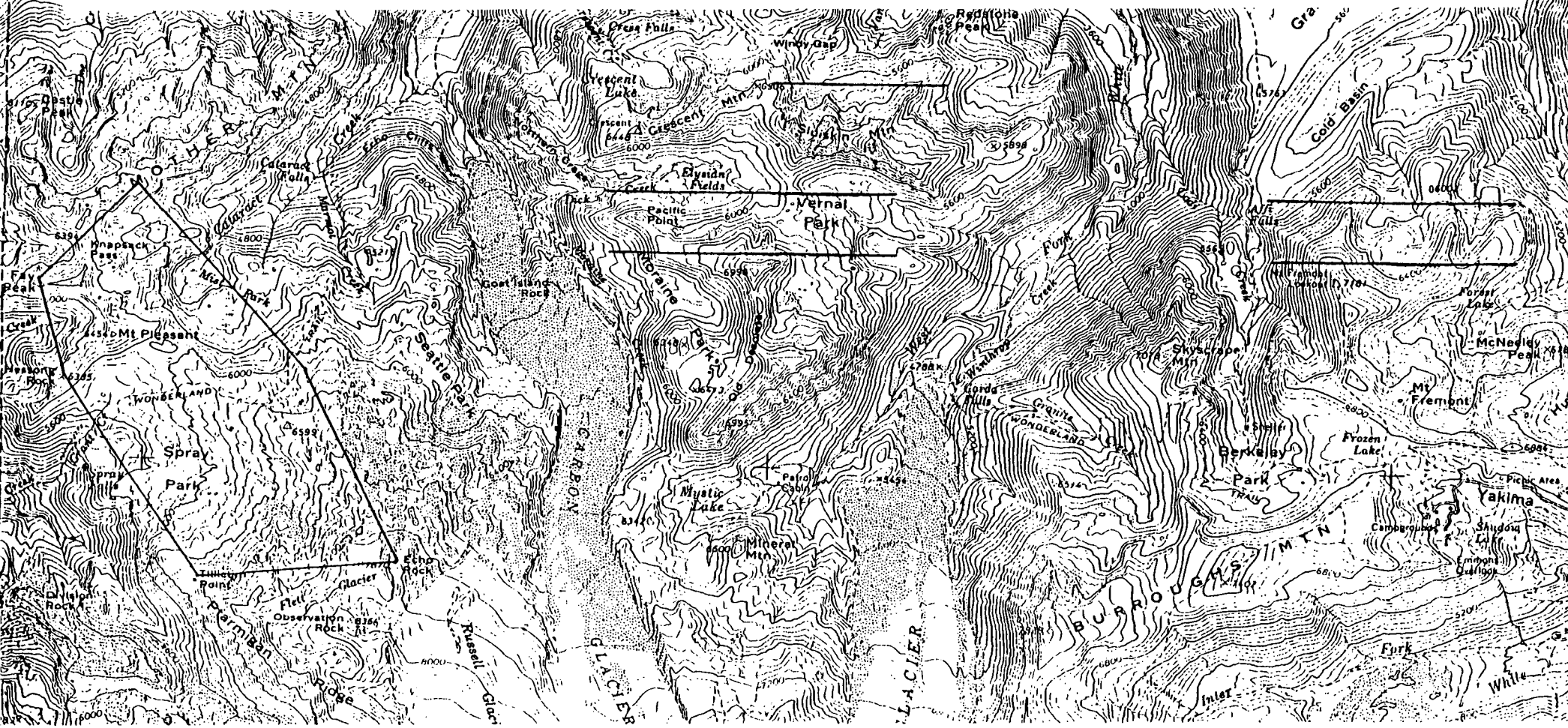
MT. RAINIER NATIONAL PARK



ELK IMPACTS STUDY

AUGUST 4, 1987 AERIAL PHOTOGRAPHY

MT. RAINIER NATIONAL PARK



APPENDIX II

Elk Trail Enumerations:

Tabular

and

Photographic

UPPER HUCKLEBERRY BASIN

TRAIL ENUMERATION - 1985
Scale = 1:2,500 Area = .068245 Km^2

Trail ARC #	Trail Width (M)	Vegetation Width (M)	Bare Soil Width (M)	Trail Length (M)	Area of Bare Soil (M^2)	Photo Number

NO ELK TRAILS WERE FOUND IN THIS ENUMERATION AREA.

SUNRISE LAKE

TRAIL ENUMERATION - 1985
Scale = 1:2,500 Area = .105548 Km^2

Trail ARC #	Trail Width (M)	Vegetation Width (M)	Bare Soil Width (M)	Trail Length (M)	Area of Bare Soil (M^2)	Photo Number
1	.47	.05	.42	25.7	10.8	1
2	.48	.08	.40	19.9	8.0	2
3	.32	.09	.23	24.2	5.6	3
4	.39	.07	.32	23.2	7.4	4
5	.42	.04	.38	20.0	7.6	5
6	.35	.08	.27	52.5	14.2	6
	$\bar{x}$ .41	$\bar{x}$ .07	$\bar{x}$ .34	Σ165.5M	Σ53.6M^2	

The trail and vegetation widths displayed are an average of three (3) observations per arc.

BEAR PARK

TRAIL ENUMERATION - 1985
Scale = 1:2,500 Area = .075807 Km^2

Trail ARC #	Trail Width (M)	Vegetation Width (M)	Bare Soil Width (M)	Trail Length (M)	Area of Bare Soil (M^2)	Photo Number
1	.44	.08	.36	91.1	32.8	2
2	.49	.03	.46	90.6	41.7	3
3	.44	.02	.42	67.0	28.1	4
4	.42	.08	.34	10.7	3.6	5
5	.60	.04	.56	8.8	4.9	6
6	.61	.02	.59	13.4	7.9	7
7	.41	.02	.39	29.7	11.6	8
8	.38	.07	.31	23.0	7.1	9
12	.44	.01	.43	24.6	10.6	13
13	.38	.01	.37	9.4	3.5	14
14	.48	.08	.40	38.3	15.3	15
15	.53	.11	.42	63.3	26.6	16
16	.40	.05	.35	28.5	10.0	17
	$\bar{x}$ .46	$\bar{x}$ .05	$\bar{x}$ .42	Σ498.4	Σ203.7	

The trail and vegetation widths displayed are an average of three (3) observations per arc.

CLOVER LAKE

TRAIL ENUMERATION - 1985

Scale = 1:2,500 Area = .166856 Km^2

Trail ARC #	Trail Width (M)	Vegetation Width (M)	Bare Soil Width (M)	Trail Length (M)	Area of Bare Soil (M^2)	Photo Number
2	.41	.13	.28	89.0	24.9	8
4	.33	.03	.30	55.3	16.6	9
5	.39	.03	.36	89.8	32.3	10
6	.43	.06	.37	31.7	11.7	11
7	.42	.04	.38	106.8	40.6	12
8	.32	.02	.30	16.1	4.8	13
10	.43	.03	.40	74.6	29.8	14
11	.30	.03	.27	27.8	7.5	15
12	.35	.03	.32	64.0	20.5	16
13	.33	.02	.31	20.6	6.4	17
14	.34	.07	.27	81.9	22.1	18
15	.39	.08	.31	85.3	26.4	19
16	.30	.03	.27	56.9	15.4	20
17	.35	.02	.33	312.4	103.1	21
18	.32	.06	.26	20.0	5.2	6
19	.33	.03	.30	31.5	9.4	(Roll 2) 3
20	.39	.01	.38	31.3	11.9	7
21	.34	.02	.32	60.9	19.5	9
22	.46	.00	.46	40.2	18.5	11
23	.44	.08	.36	20.9	7.5	12
24	.54	.04	.50	99.3	49.7	10
25	.41	.00	.41	76.2	31.2	13
26	.35	.02	.33	82.4	27.2	14
27	.26	.01	.25	21.7	5.4	15
28	.30	.03	.27	20.2	5.4	16
29	.48	.04	.44	44.5	19.6	17
30	.36	.06	.30	45.1	13.5	18
31	.37	.06	.31	13.7	4.2	20
32	.36	.09	.27	23.0	6.2	24
33	.62	.02	.60	12.2	7.3	19
34	.37	.02	.35	12.3	4.3	21
35	.37	.02	.35	17.7	6.2	22
36	.45	.01	.44	13.9	6.1	23
37	.32	.01	.31	40.2	12.5	25
38	.38	.01	.37	27.3	10.1	26
39	.44	.01	.43	31.7	13.6	27,28
41	.45	.00	.45	115.5	52.0	29
42	.34	.08	.26	39.1	10.2	30
43	.44	.02	.42	42.0	17.6	31
44	.47	.01	.46	37.3	17.2	32
45	.30	.09	.21	38.0	8.0	33
	$\bar{x}$ .38	$\bar{x}$ .04	$\bar{x}$ .35	Σ2,170.3	Σ761.6	

The trail and vegetation widths displayed are an average of three (3) observations per arc.

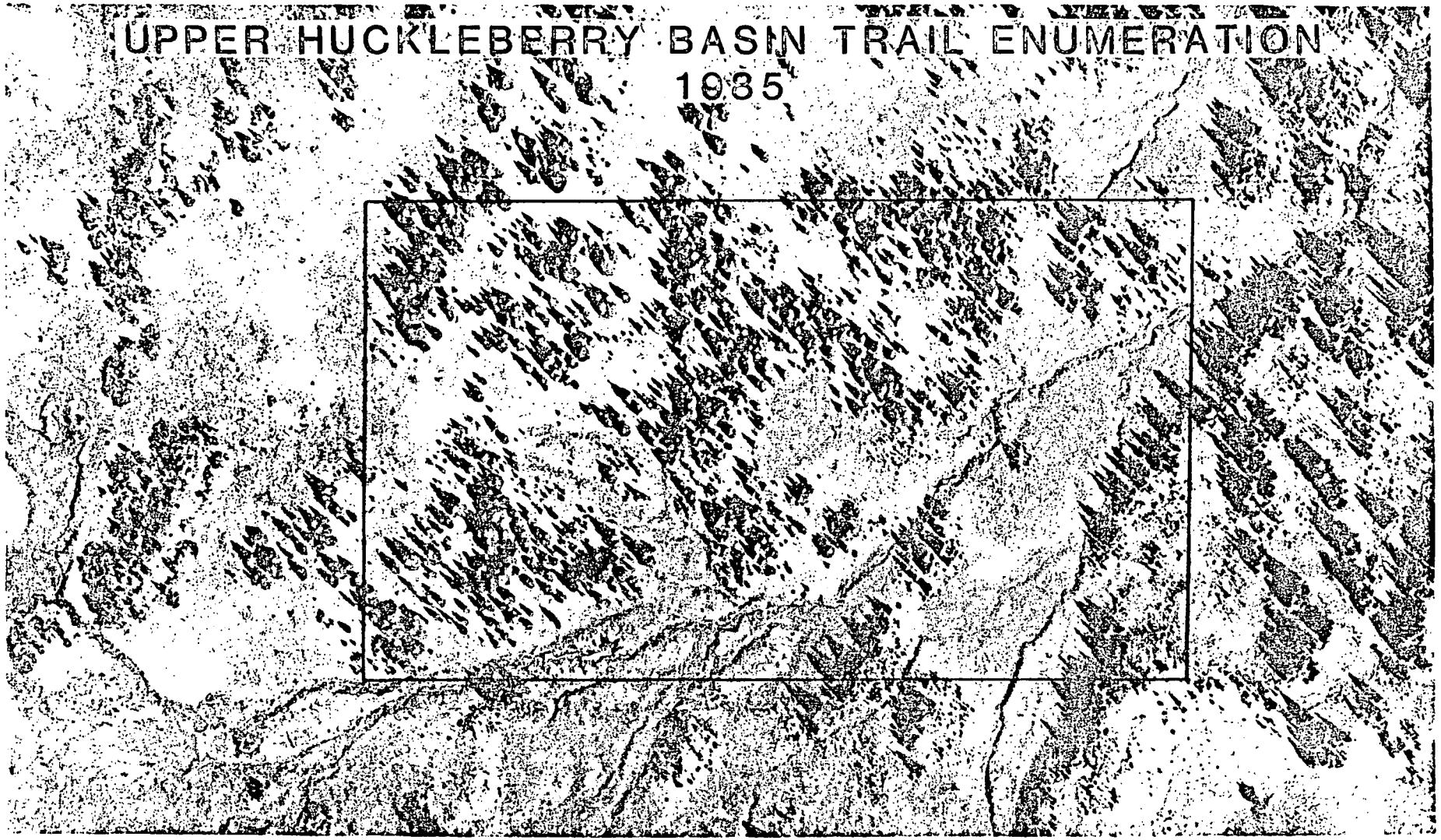
LOWER HUCKLEBERRY BASIN

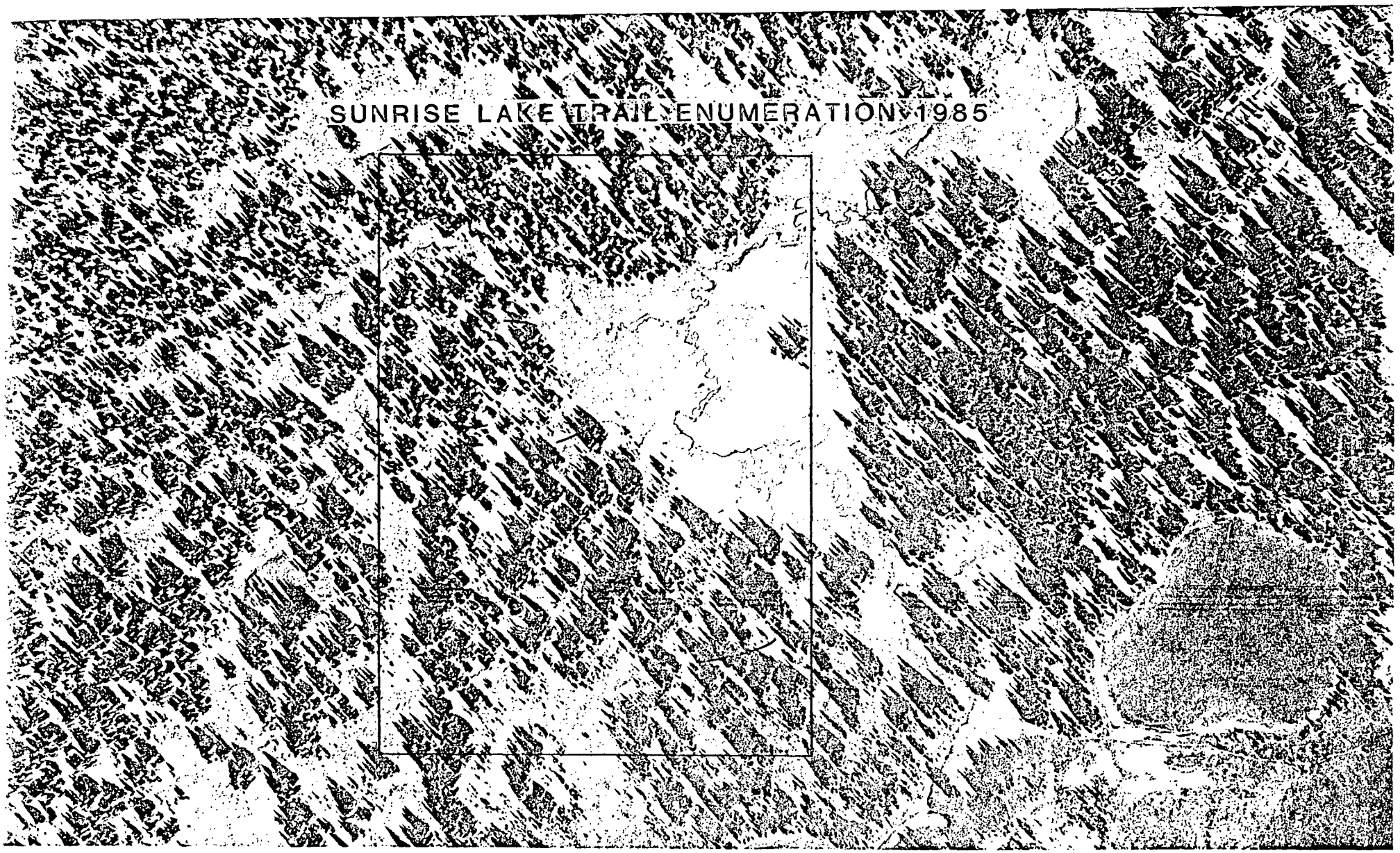
TRAIL ENUMERATION - 1985

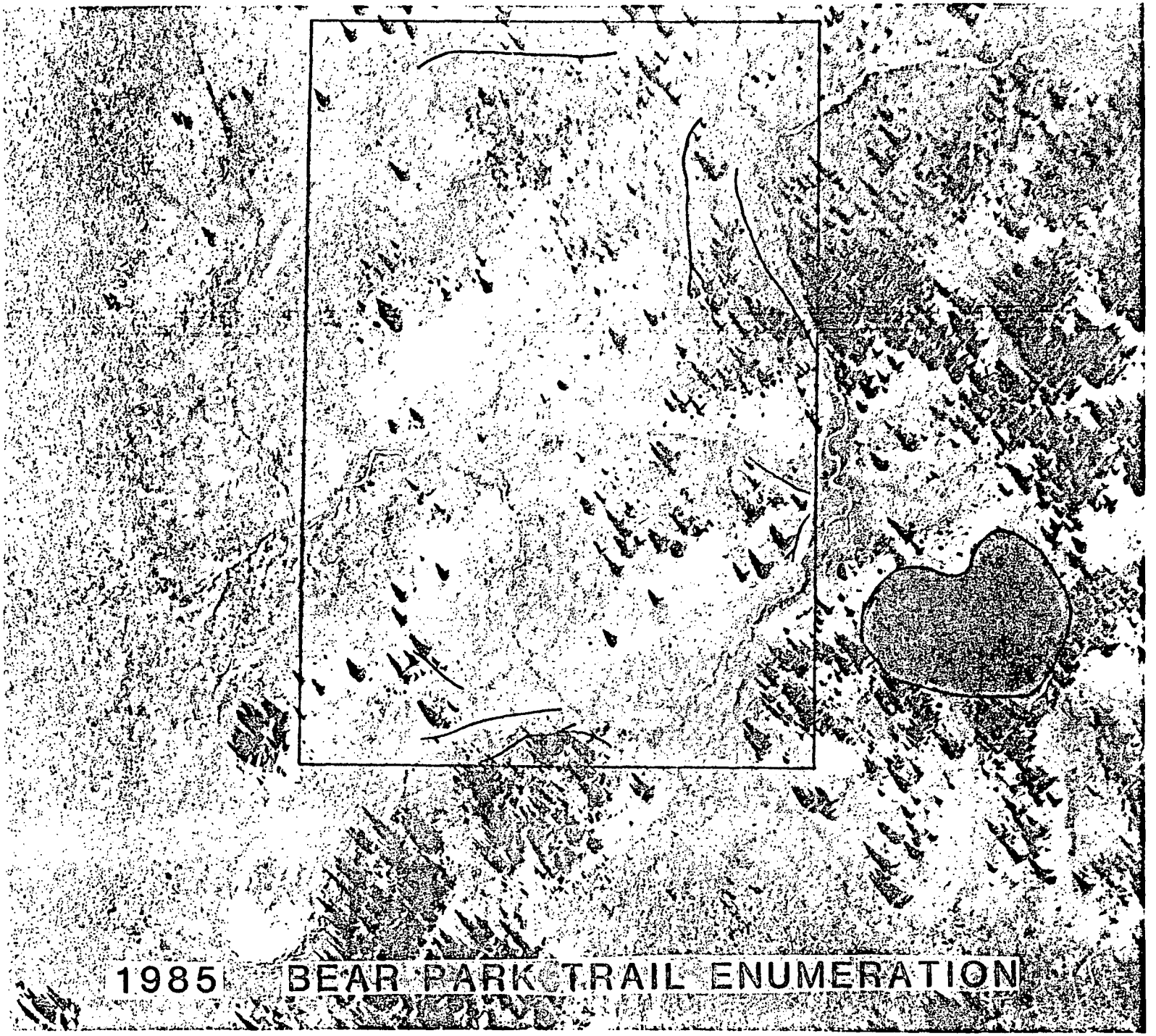
Scale = 1:2,500 Area = .104175 Km^2

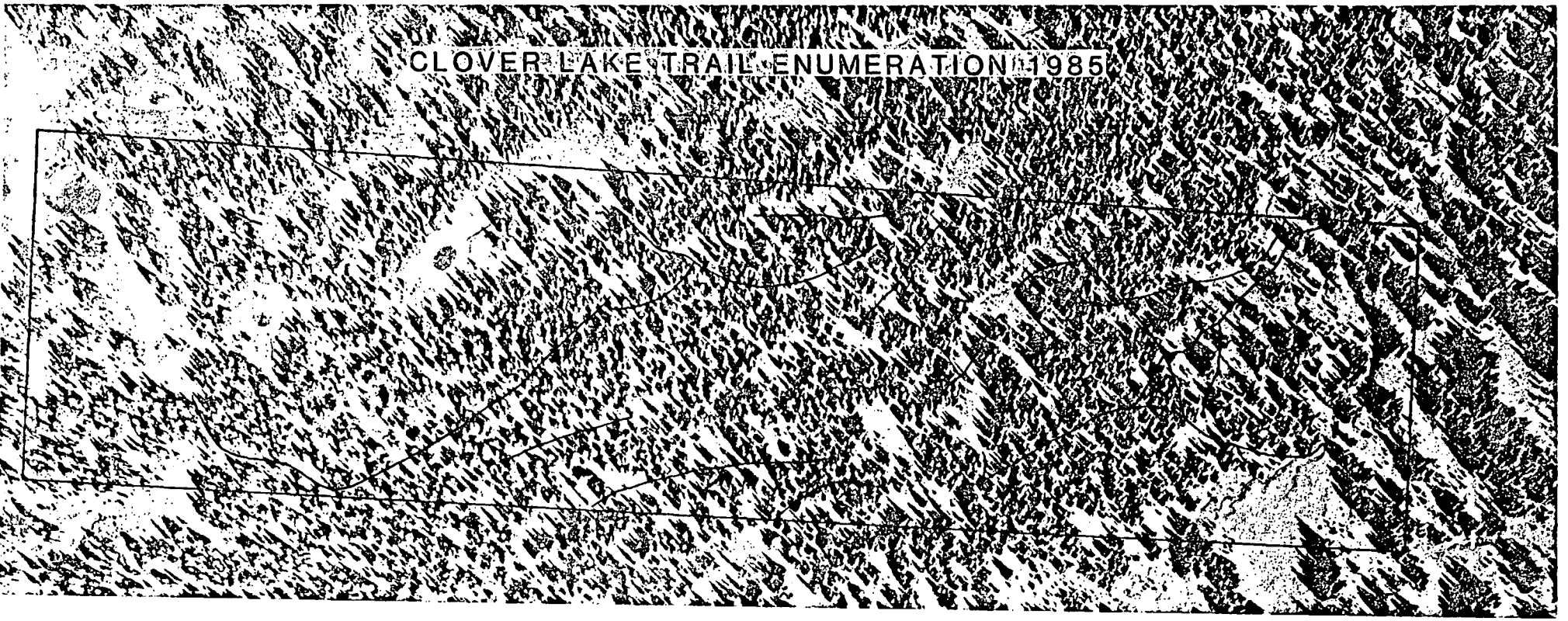
Trail ARC #	Trail Width (M)	Vegetation Width (M)	Bare Soil Width (M)	Trail Length (M)	Area of Bare Soil (M^2)	Photo Number
1	.49	.00	.49	22.3	10.9	5
2	.42	.02	.40	16.0	6.4	5
3	.50	.00	.50	92.7	46.4	8
4	.43	.07	.36	111.8	40.2	4
5	.27	.09	.18	15.6	2.8	6
6	.42	.00	.42	53.6	22.5	7
7	.51	.01	.50	75.6	37.8	9
8	.45	.02	.43	36.2	15.6	10
9	.42	.03	.39	15.0	5.9	11
10	.42	.04	.38	25.0	9.5	12
11	.55	.01	.54	24.9	13.4	13
12	.50	.01	.49	38.8	19.0	14
13	.64	.00	.64	26.4	16.9	15
14	.60	.00	.60	16.5	9.9	16
15	.50	.00	.50	13.2	6.6	15
16	.40	.02	.38	42.7	16.2	17
17	.42	.02	.40	26.0	10.4	17
18	.49	.02	.47	31.0	14.6	18
19	.60	.04	.56	30.4	17.0	19
20	.40	.04	.36	77.2	27.8	20
21	.39	.02	.37	42.9	15.9	21
23	.45	.07	.38	16.4	6.2	22
24	.43	.00	.43	20.1	8.6	24
25	.41	.05	.36	24.5	8.8	22
26	.31	.03	.28	16.4	4.6	23
27	.41	.05	.36	15.8	5.7	25
28	.37	.07	.30	43.6	13.1	26
29	.51	.01	.50	334.5	167.2	27
31	.37	.04	.33	24.5	8.1	28
33	.42	.03	.39	9.3	3.6	30
34	.48	.04	.44	13.3	5.9	31
35	.50	.00	.50	16.9	8.4	33
37	.36	.03	.33	37.2	12.3	35
39	.38	.02	.36	46.2	16.6	31
43	.45	.01	.44	31.6	13.9	36
44	.42	.02	.40	26.6	10.6	37
	$\bar{x}$ .45	$\bar{x}$ .03	$\bar{x}$ .42	Σ1510.7	Σ659.3	

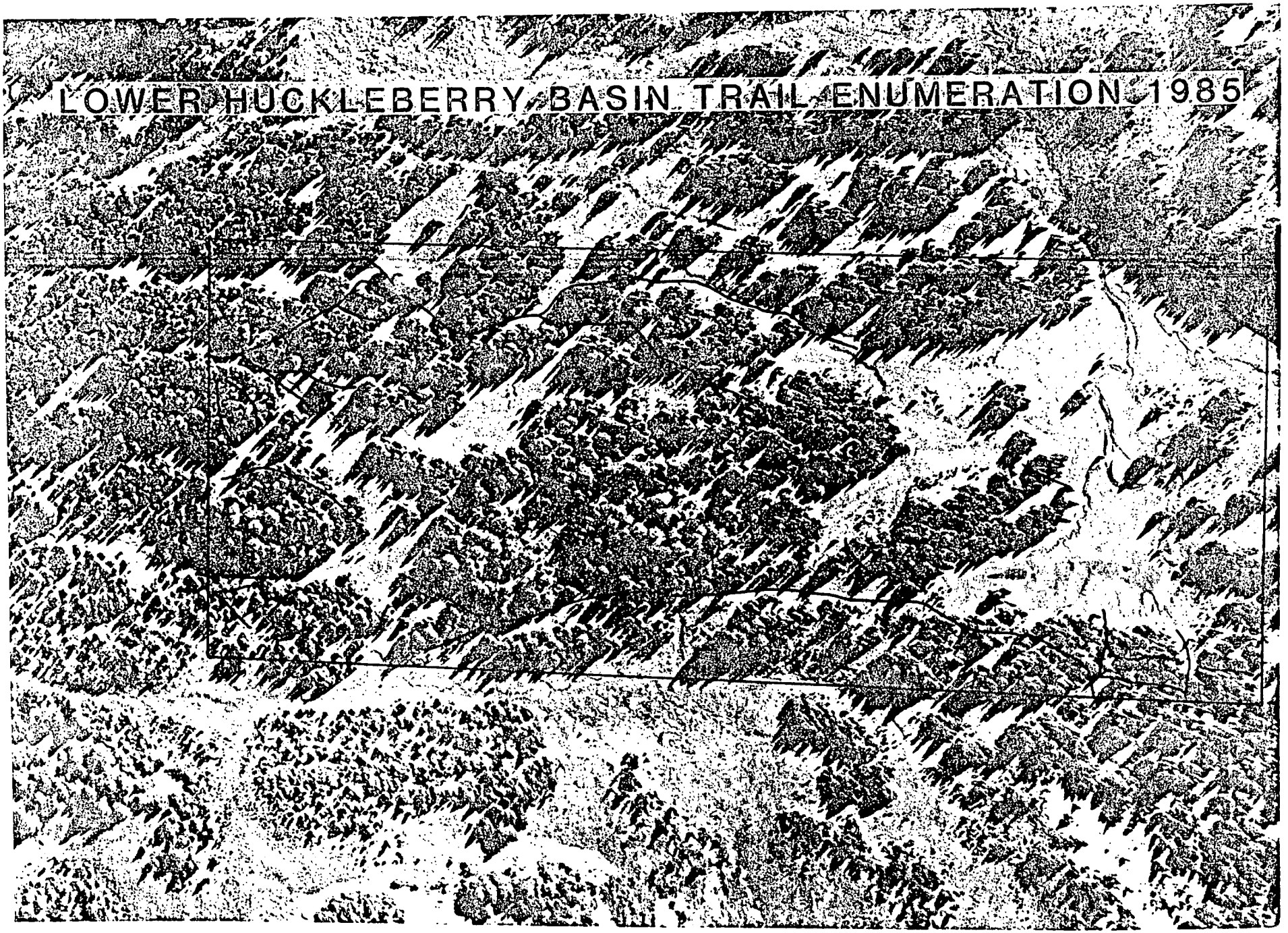
The trail and vegetation widths displayed are an average of three (3) observations per arc.


UPPER HUCKLEBERRY BASIN TRAIL ENUMERATION
1985


SUNRISE LAKE TRAIL ENUMERATION 1985


1985 BEAR PARK TRAIL ENUMERATION


CLOVER LAKE TRAIL ENUMERATION 1985


LOWER HUCKLEBERRY BASIN TRAIL ENUMERATION 1985

APPENDIX III

Comparison and Accuracy Assessment

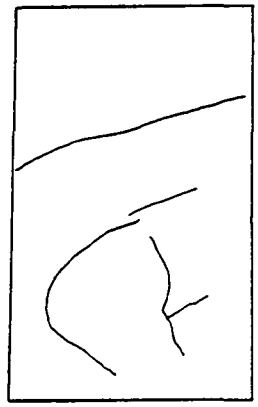
of

Photointerpretation

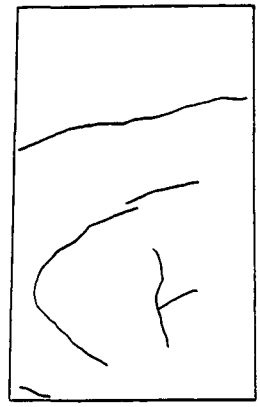
with Ground Truth

BEAR PARK NORTH SITE

PHOTO INTERPRETATION



GROUND TRUTH



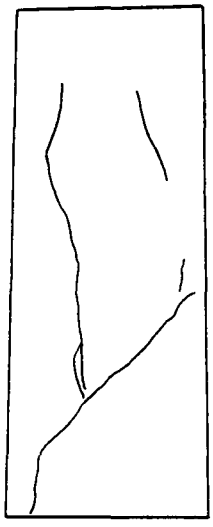
Scale **1:2112**

	Photo Interpretation	Ground Truth
Total Trail Length	**191.1 m**	**193.7 m**
Average Trail Width		**0.43 m**

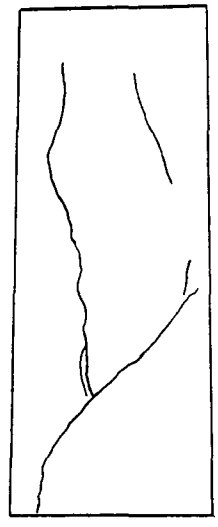
Accuracy **92.4%**

BEAR PARK EAST SITE

PHOTO INTERPRETATION



GROUND TRUTH

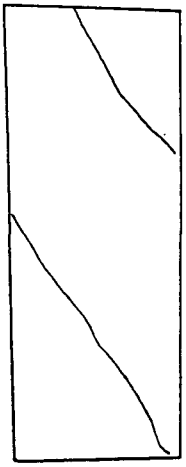


Scale **1:2251**

	Photo Interpretation	Ground Truth
Total Trail Length	**245.8 m**	**256.1 m**
Average Trail Width		**0.40 m**
Accuracy	**95.8%**	

BEAR PARK RIDGE

PHOTO INTERPRETATION



GROUND TRUTH

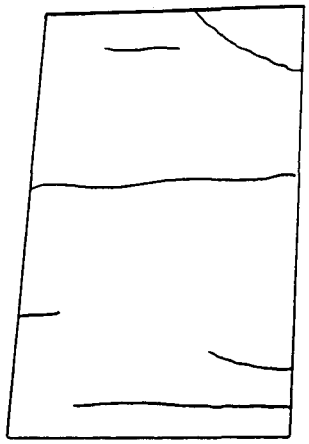
Scale 1:2112

	Photo Interpretation	Ground Truth
Total Trail Length	128.8 m	198.7 m
Average Trail Width		0.59 m

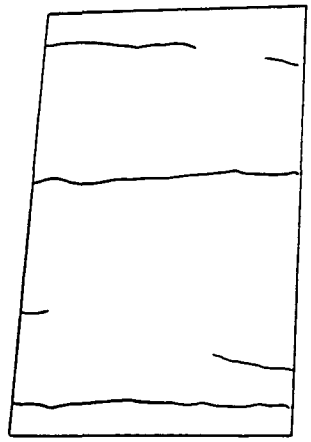
Accuracy 64.8%

GREEN PARK RIDGE

PHOTO INTERPRETATION



GROUND TRUTH



Scale **1:2130**

	Photo Interpretation	Ground Truth
Total Trail Length	**220.2 m**	**251.4 m**
Average Trail Width		**0.52 m**

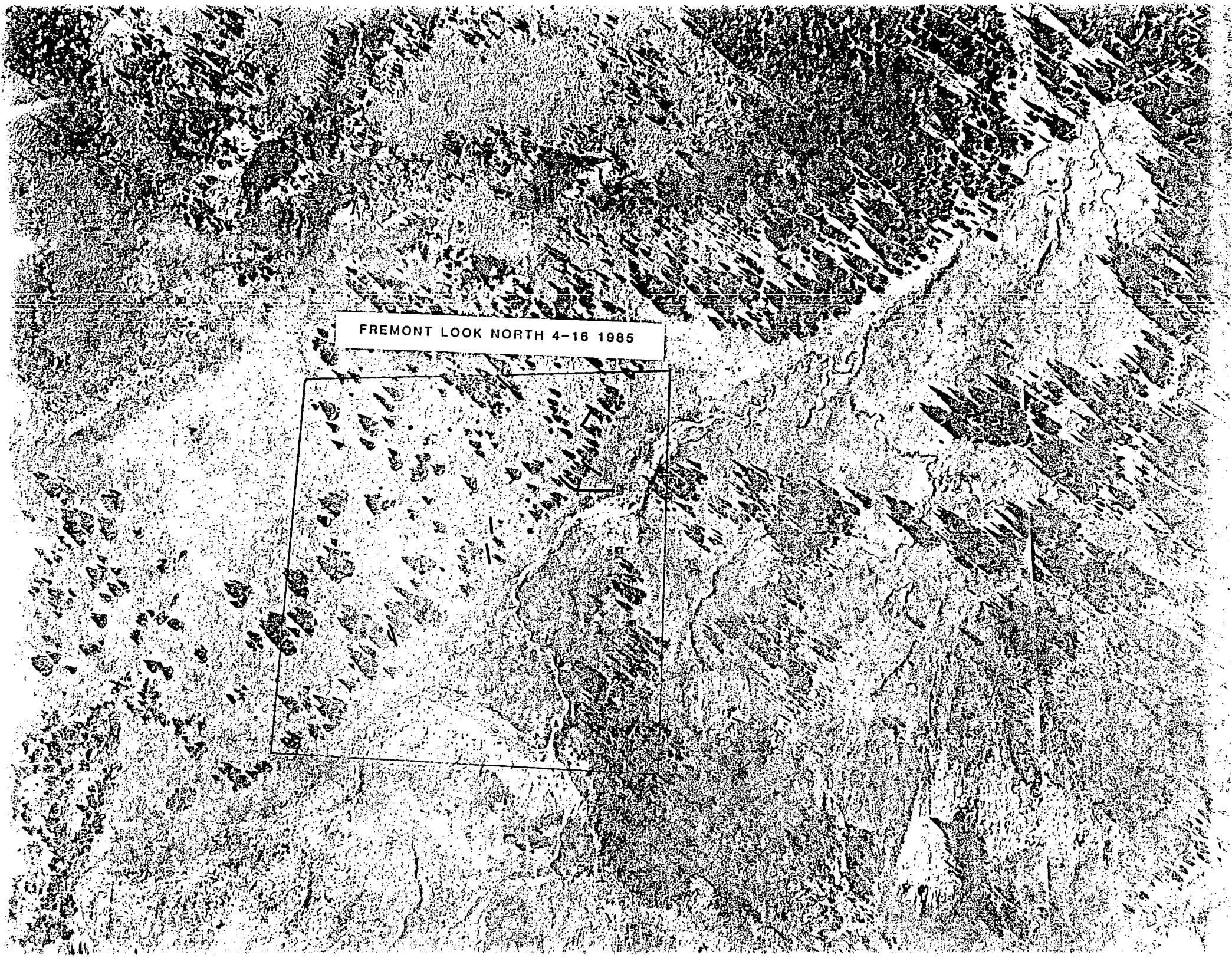
Accuracy **61.0%**

APPENDIX IV

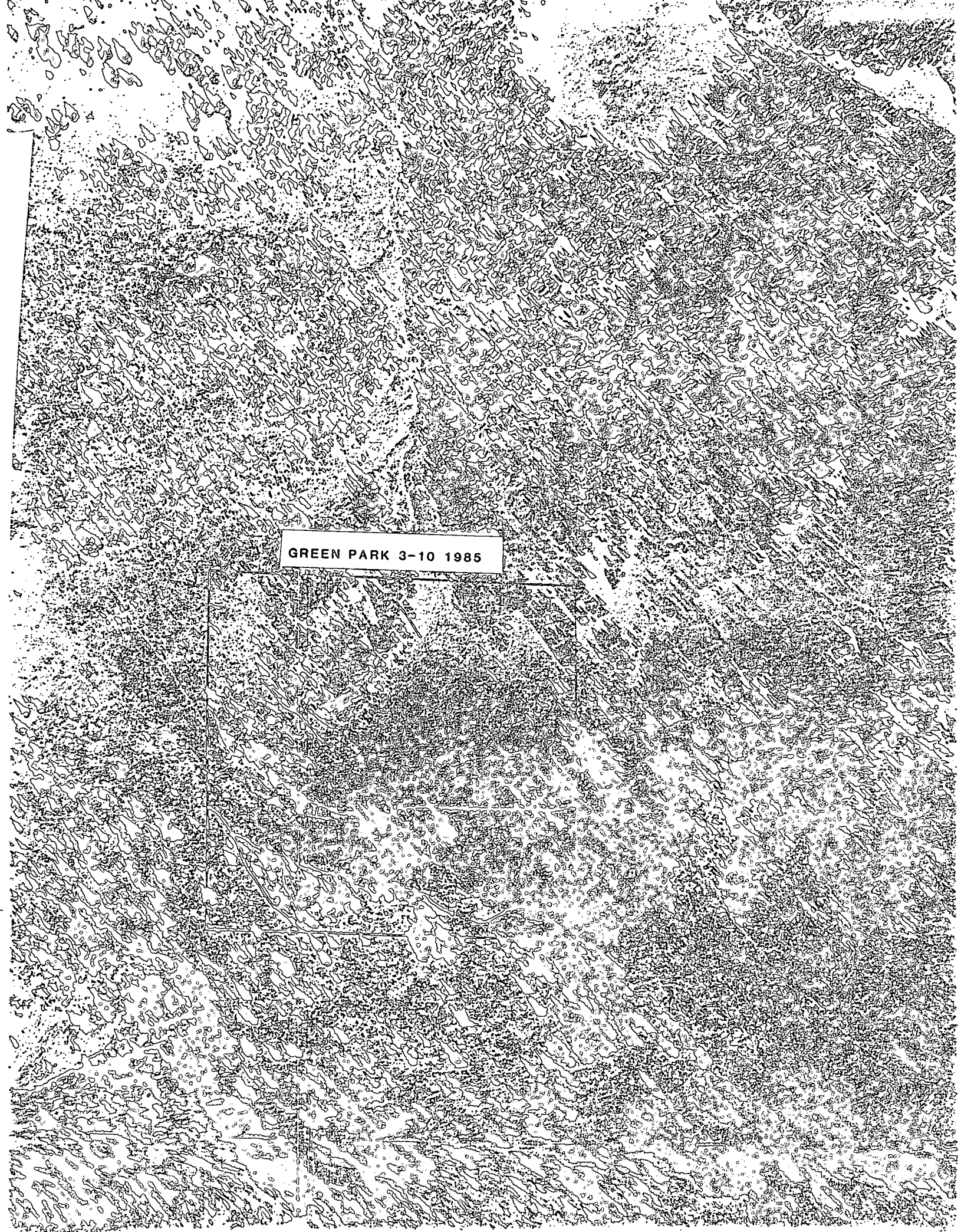
Photo Plots Associated with

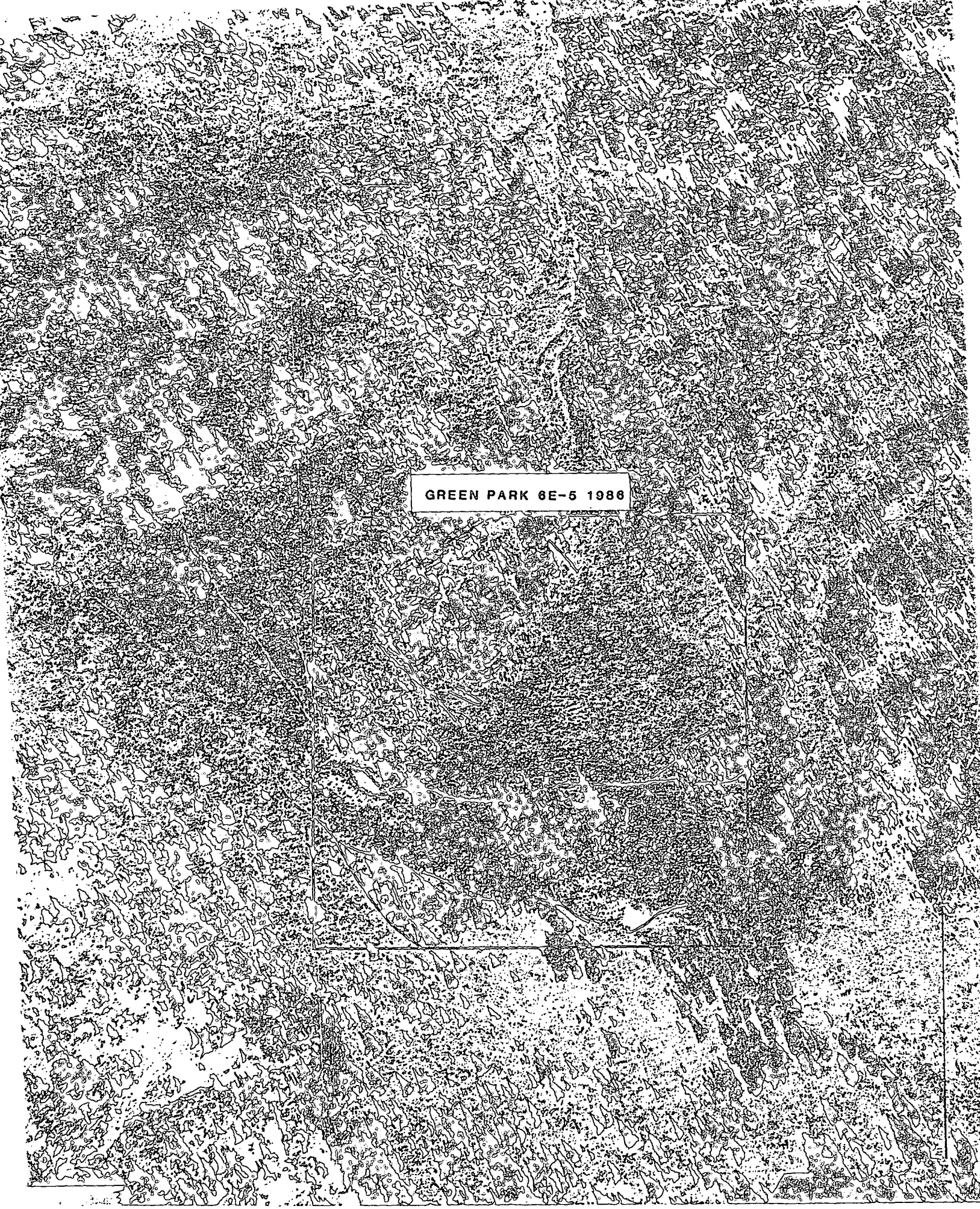
Ten Sites

for Monitoring Elk Trails

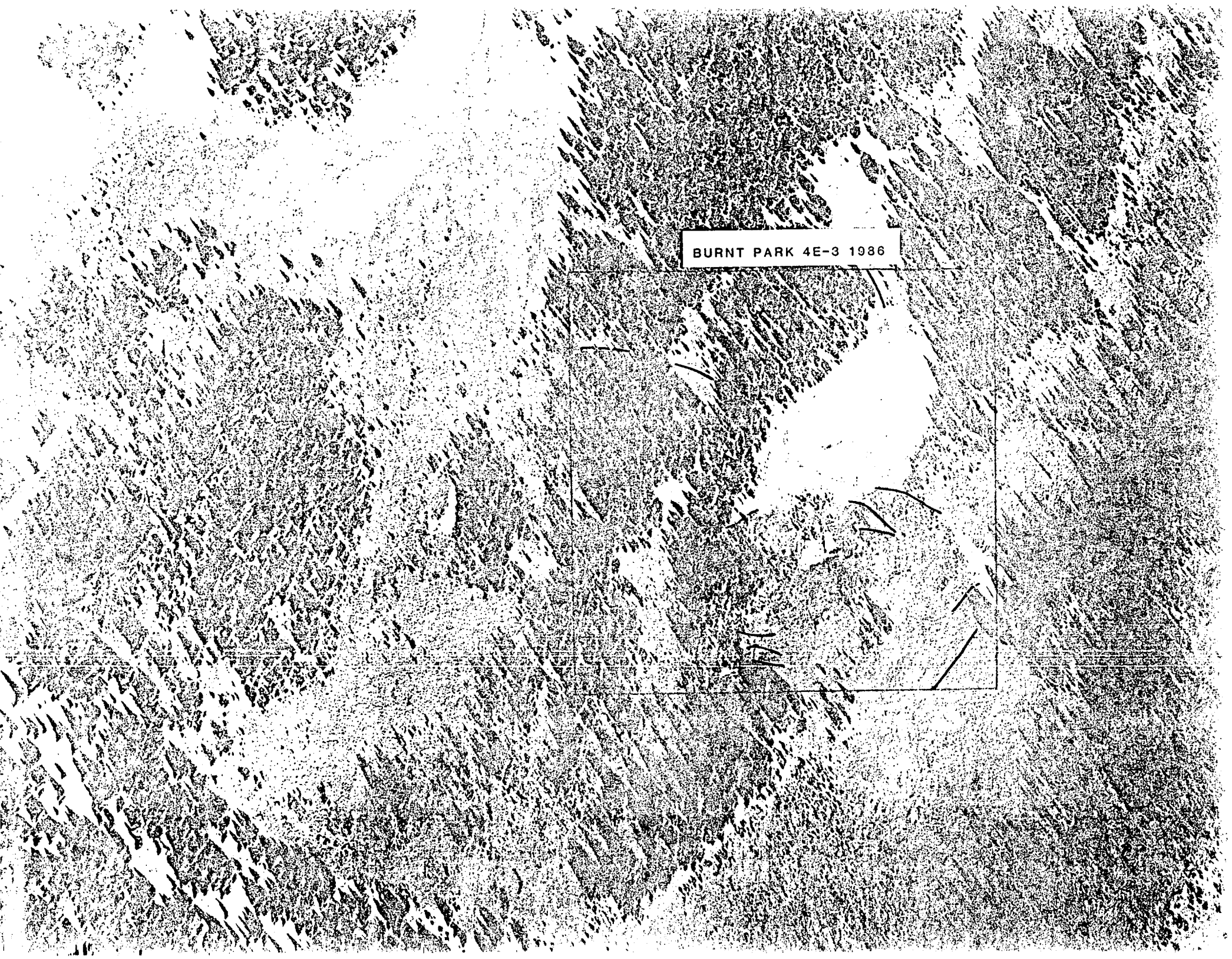

FREMONT LOOK NORTH 4-16 1985

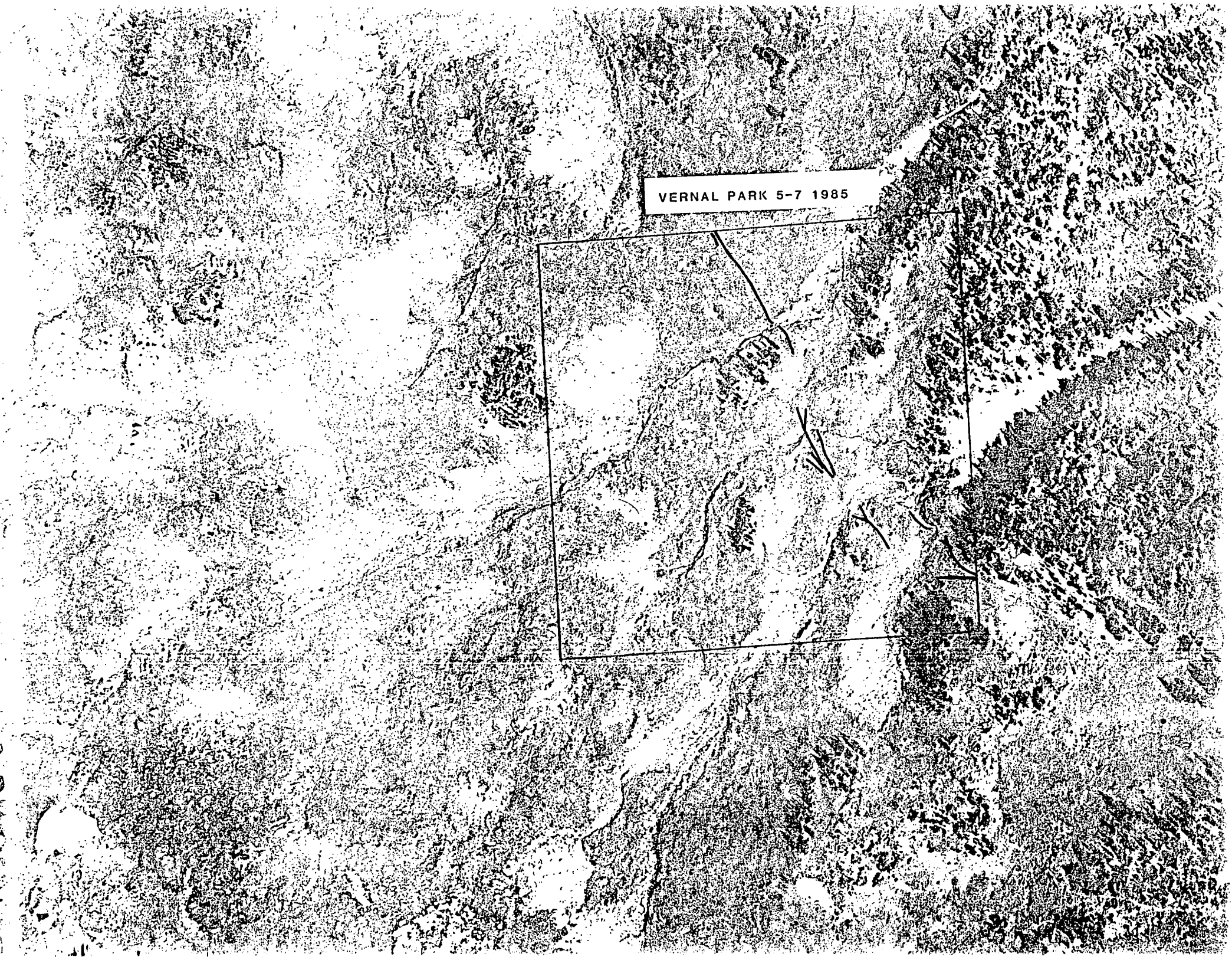

FREMONT LOOKOUT NORTH 7E-4 1986

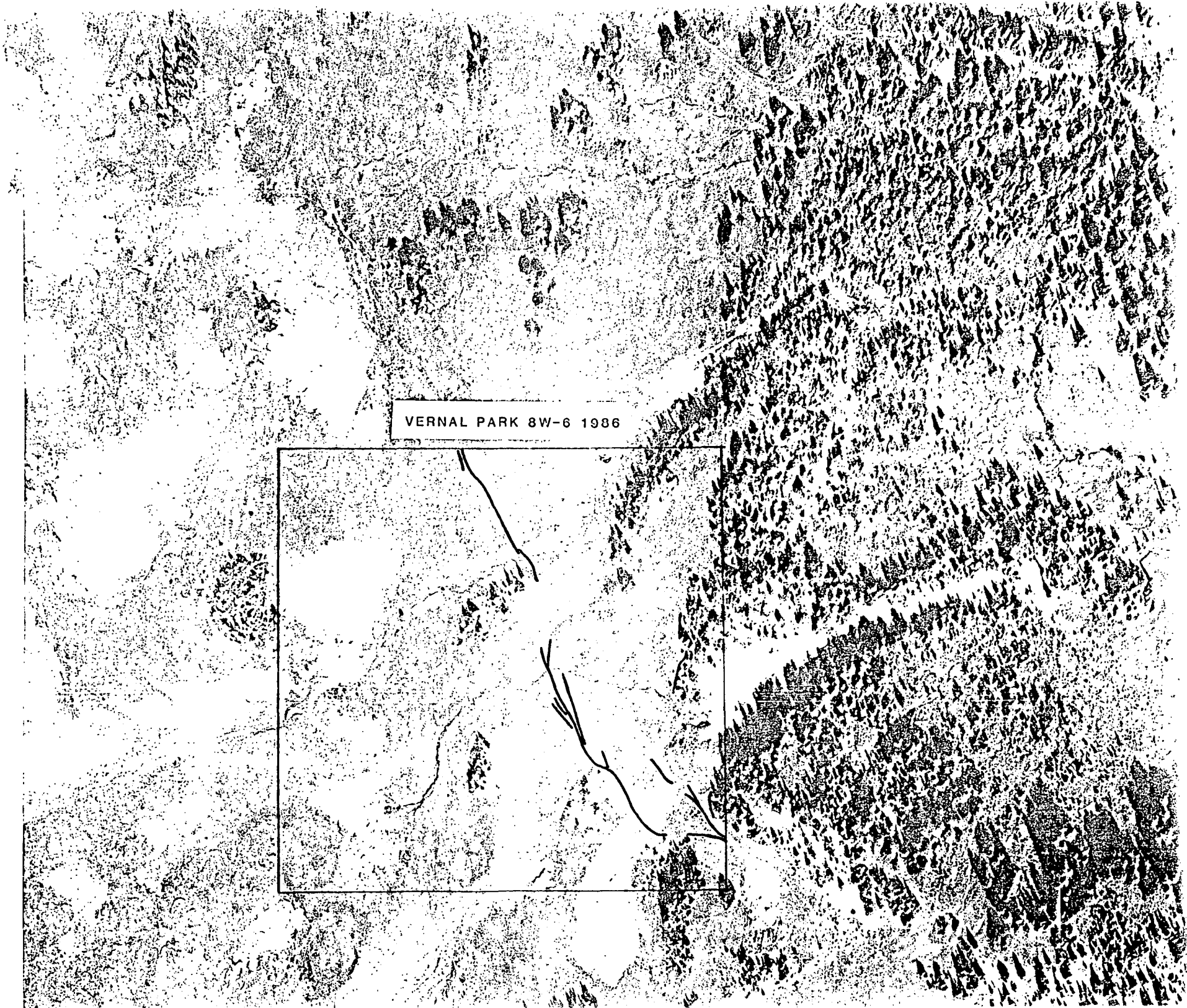

GREEN PARK 3-10 1985

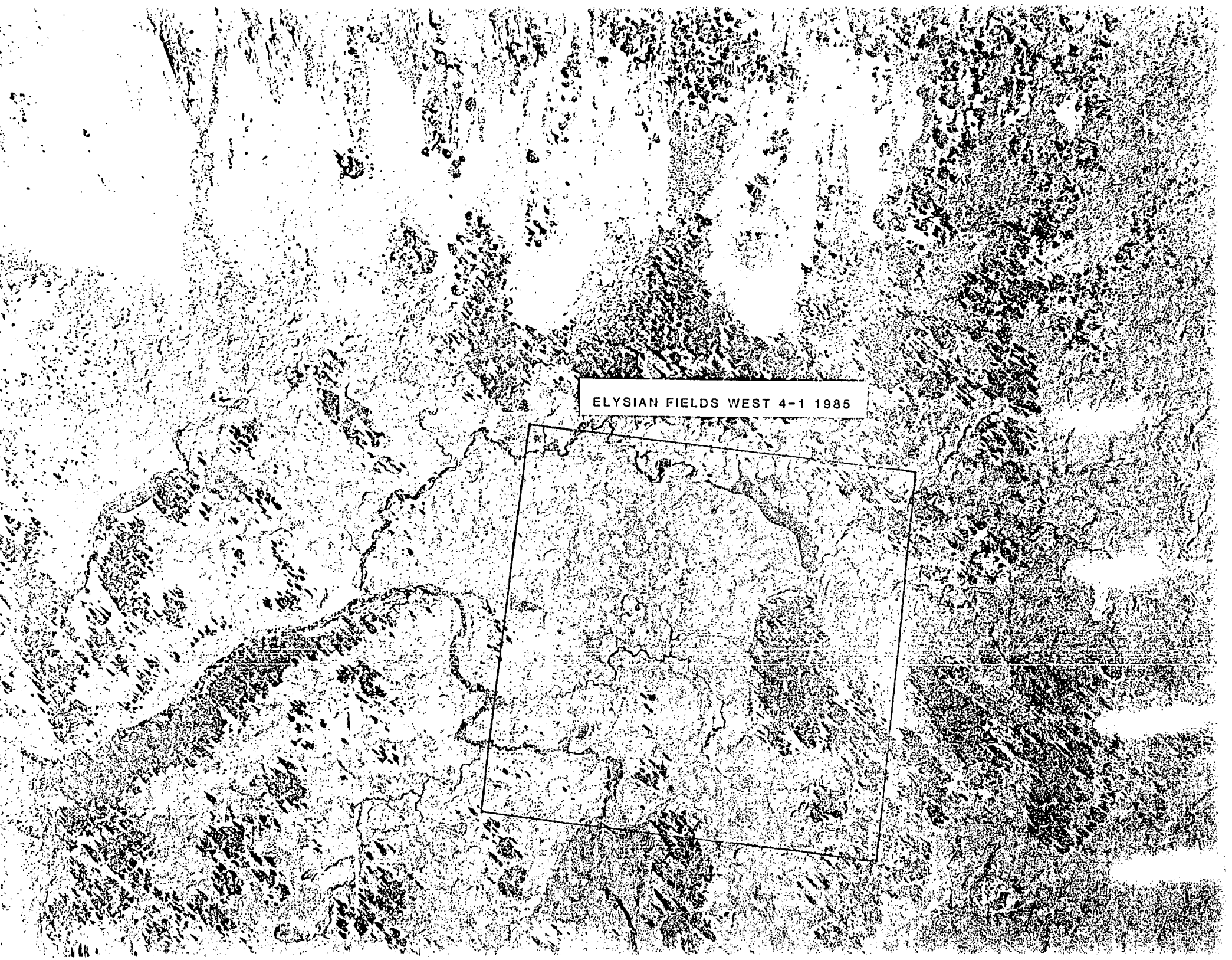

GREEN PARK 6E-5 1986

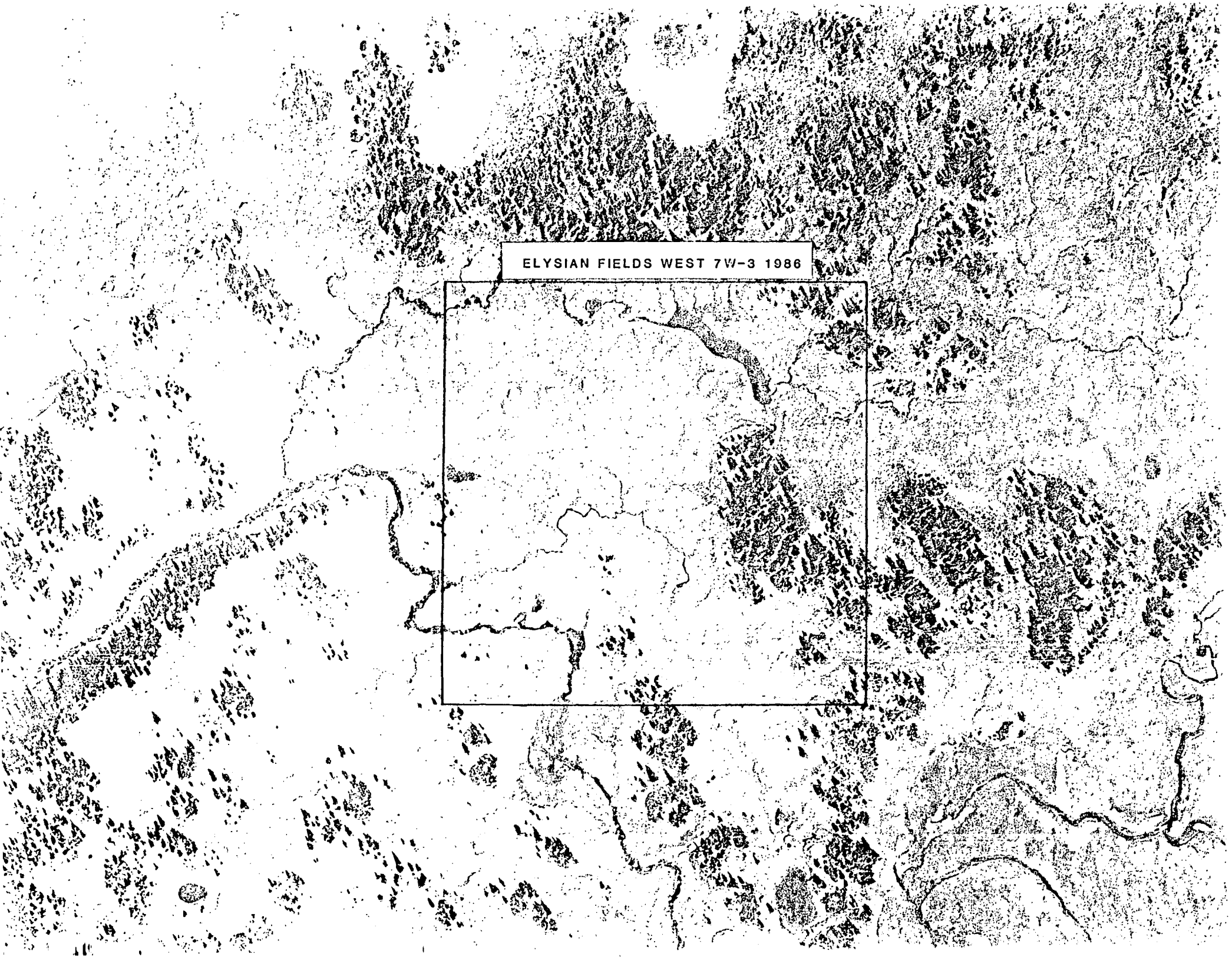
BURNT PARK 1-11 1985

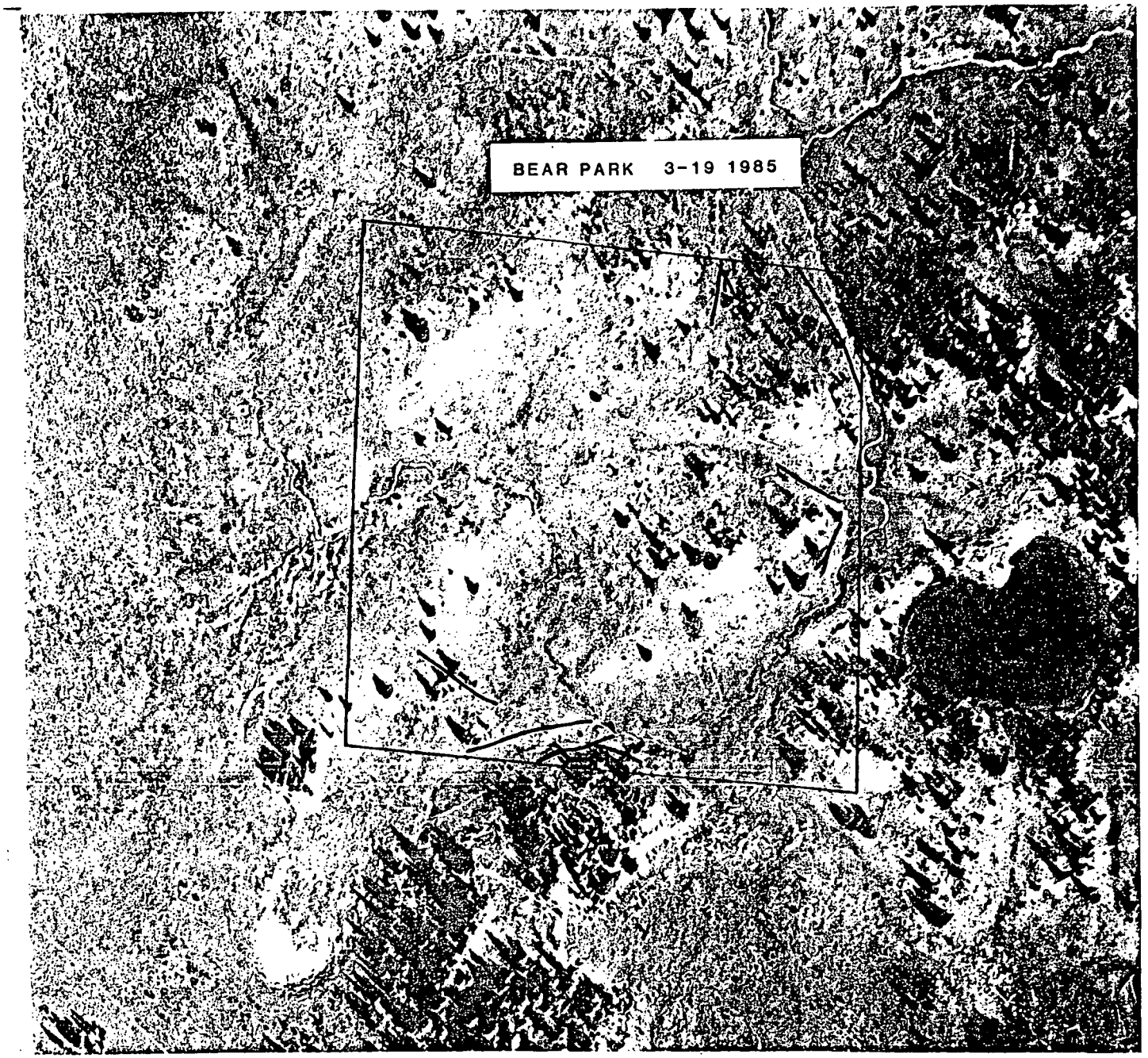

BURNT PARK 4E-3 1986

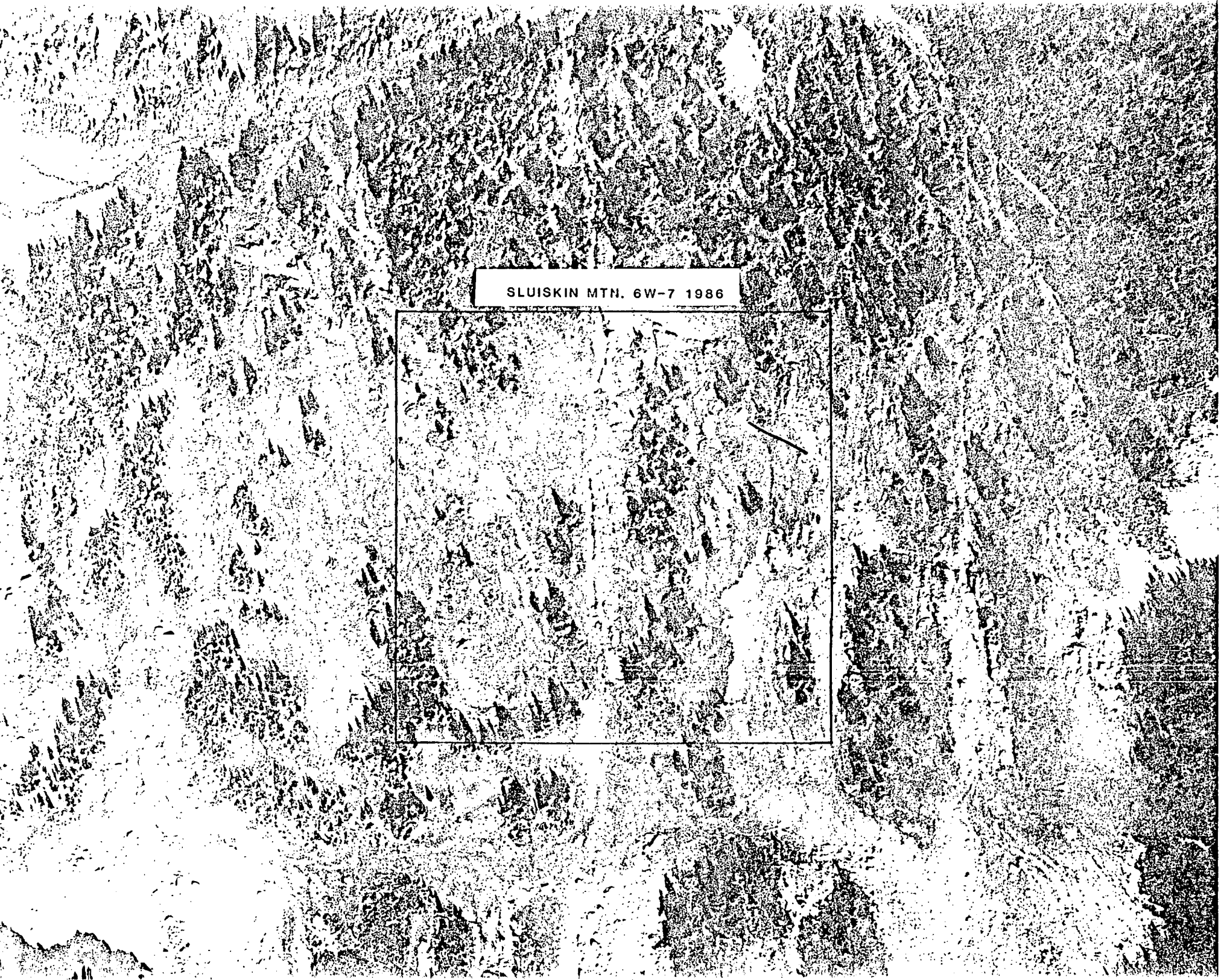

VERNAL PARK 5-7 1985

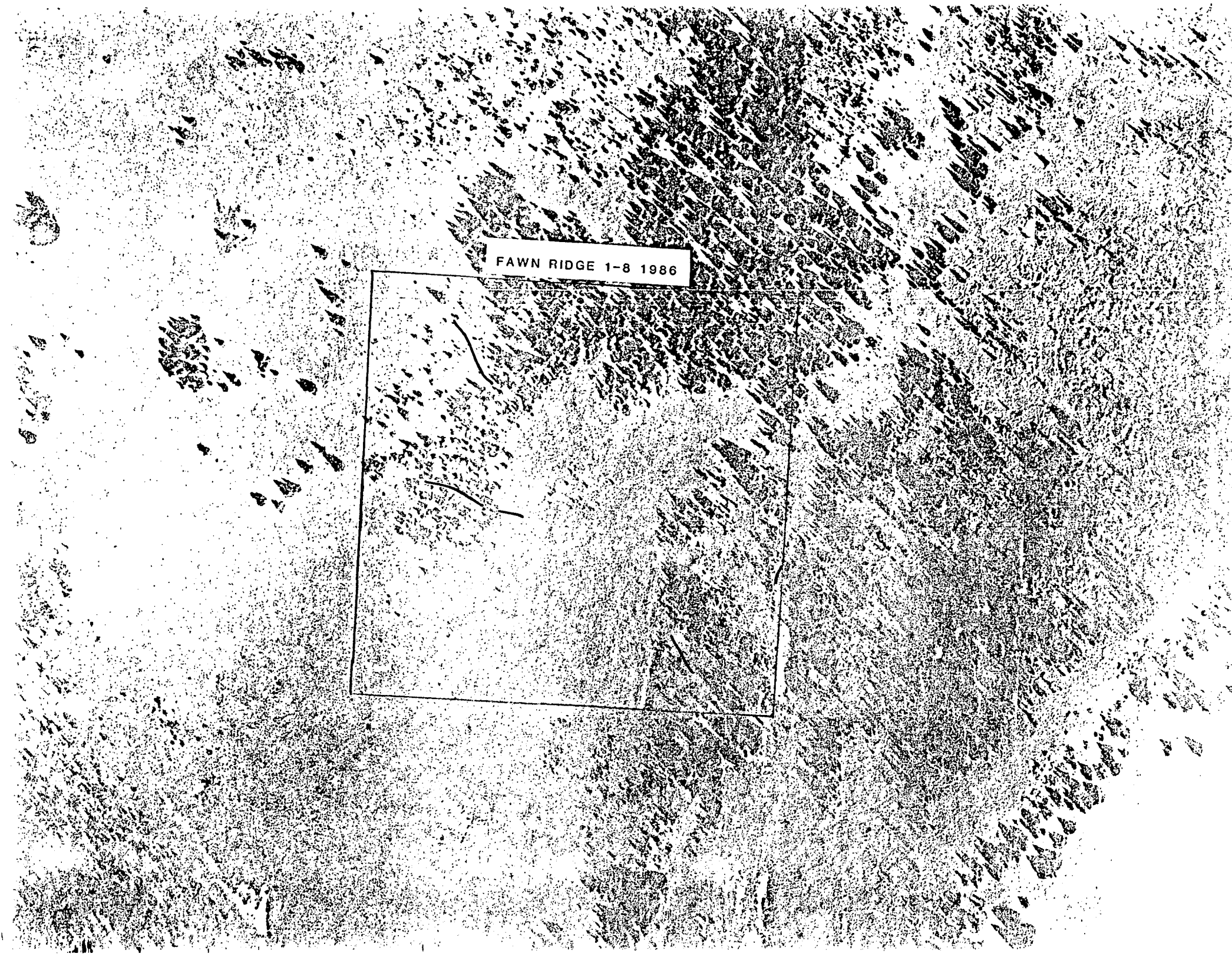

VERNAL PARK 8W-6 1986

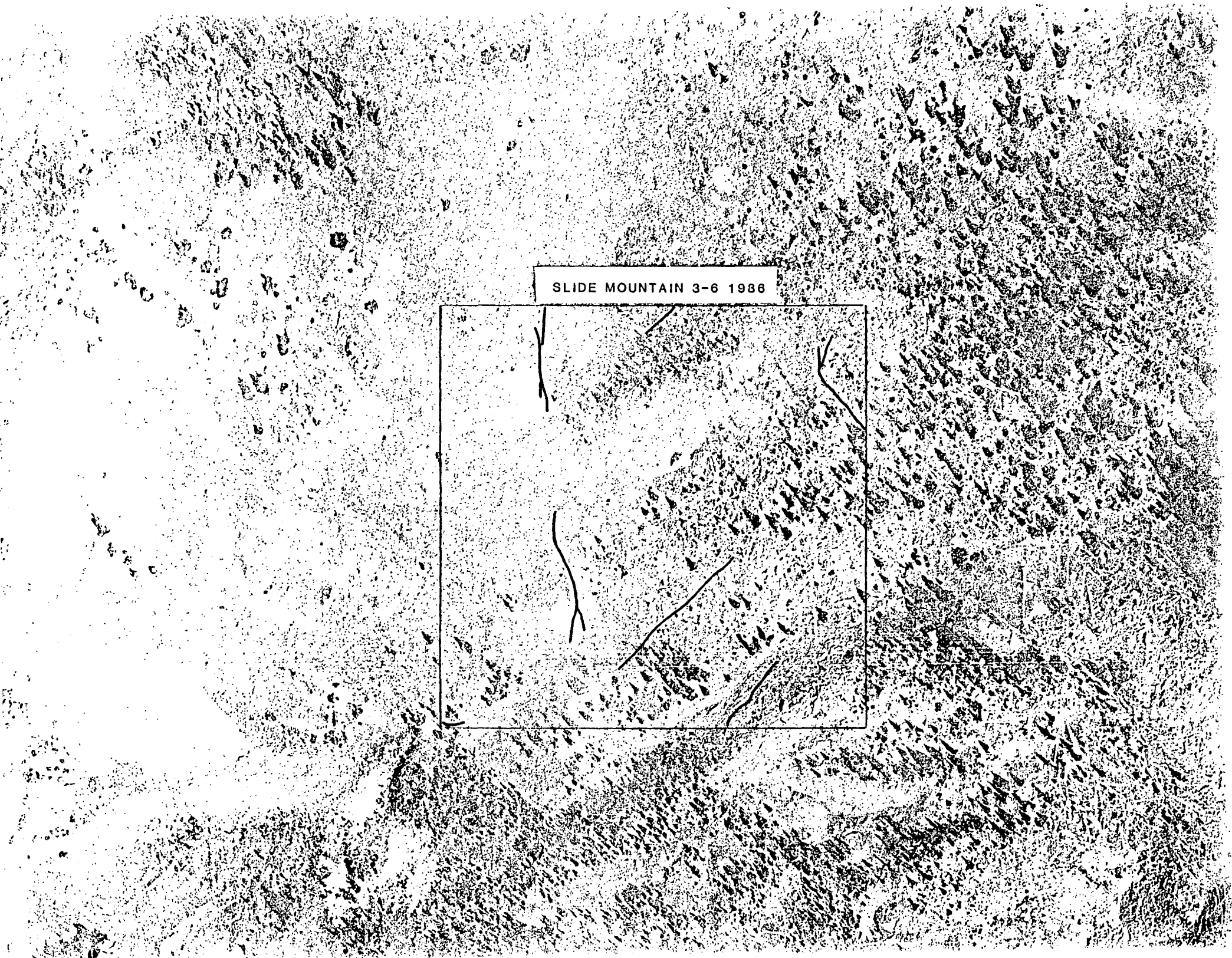

ELYSIAN FIELDS WEST 4-1 1985

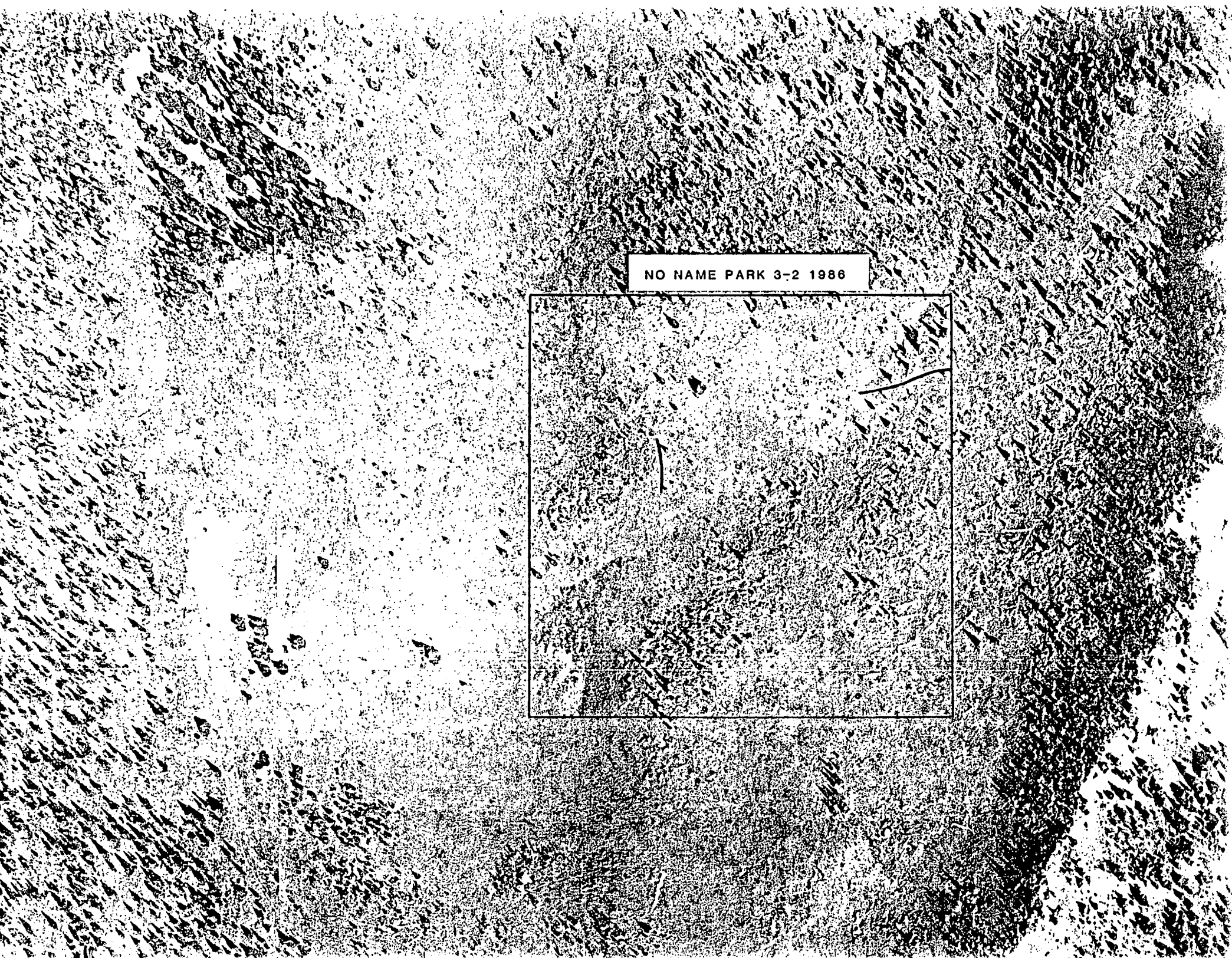

ELYSIAN FIELDS WEST 7W-3 1986


BEAR PARK 3-19 1985


SLUISKIN MTN. 6W-7 1986


FAWN RIDGE 1-8 1986


SLIDE MOUNTAIN 3-6 1986


NO NAME PARK 3-2 1986

APPENDIX V

Trail and Vegetation Widths

for

Fremont Basin Photo Plot

1986 and 1987

FREMONT LOOKOUT NORTH 1986

Arc	Observation	Trail Width (cm)	Vegetation Width (cm)	Photo
1	a	85	3	#23
	b	75	5	Looking northwest
	c	60	4	
	$\bar{x}$	73.3	4.0	
2	a	63	2	#24
	b	63	0	Looking northwest
	c	59	6	
	$\bar{x}$	61.7	2.7	
3	a	49	6	#1
	b	60	4	Looking north-northwest
	c	70	0	
	$\bar{x}$	59.7	3.3	
4	a	34	20	#3
	b	38	18	Looking north
	c	49	23	
	$\bar{x}$	40.3	20.3	
5	a	70	2	#4 looking north-northwest
	b	71	14	#5 looking north-northwest
	c	35	25	#6 looking west
	$\bar{x}$	58.7	13.7	
6	a	50	7	#8 looking south
	b	48	10	
	c	38	18	#9 looking south
	$\bar{x}$	45.3	11.7	
7	a	55	18	#10
	b	73	3	Looking north
	c	69	4	
	$\bar{x}$	65.7	8.3	
8	a	65	8	#12
	b	80	2	Looking south
	c	78	0	
	$\bar{x}$	74.3	3.3	
9	a	42	3	#13
	b	53	12	Looking north
	c	50	9	
	$\bar{x}$	48.3	8.0	
10	a	44	21	#14
	b	60	12	Looking north
	c	39	21	
	$\bar{x}$	47.7	18.0	
11	a	50	25	#15
	b	40	30	Looking southwest
	c	55	28	
	$\bar{x}$	48.3	27.7	
12	a	60	2	#16
	b	50	15	Looking north
	c	53	5	
	$\bar{x}$	54.3	7.3	
13	a	43	3	#17
	b	54	10	Looking north
	c	48	8	
	$\bar{x}$	48.3	7.0	
14	No measurements due to snow storm			

Average trail width 55.8cm

Average vegetation width 10.4cm

Fremont Basin Photo-Plot
Ground Truth - 8/30/87

ARC	Observation	Trail Width (cm)	Vegetation Width (cm)	Photo
1	a	79	0	#11
	b	97	3	looking northwest
	c	86	0	
		87.3	1	
2	a	66	0	#12, 13
	b	81	0	looking northwest
	c	61	0	
		69.3	0	
3	a	61	8	#14
	b	64	13	looking north-
	c	66	13	northwest
		63.7	11.3	
4	a	56	0	#15
	b	48	5	looking north
	c	38	5	
		47.3	3.3	
5	a	71	0	#16
	b	64	8	#17
	c	43	30	#18, 19v, 20, 21v*
		59.3	12.7	
6	a	79	8	#24 looking south
	b	51	3	
	c	38	25	#26 looking east
		56.0	12.0	
7	a	79	10	#25
	b	64	8	looking north
	c	61	20	
		68.0	12.7	

*v = vertical photographs

ARC	Observation	Trail Width (cm)	Vegetation Width (cm)	Photo
8	a	66	5	#27
	b	56	3	looking south
	c	66	5	
		62.7	4.3	
9	a	56	3	#28
	b	41	3	looking north
	c	41	3	
		46.0	3.0	
10	a	51	13	#29
	b	48	0	looking north
	c	38	10	
		45.7	7.7	
11	No data collected due to swarming bees			
12	a	64	5	#30
	b	53	3	looking north
	c	56	3	
		57.7	3.7	
13	a	38	8	#31
	b	46	0	looking north
	c	43	0	
		42.3	2.7	
14	No data collected due to swarming bees			

APPENDIX VI

Presence and Absence

of Elk Trails

from Aerial Photography

1985 PHOTOGRAPHY
ELK TRAIL SAMPLING

PHOTO #	Cell # 1		Cell # 2		Cell # 3		Cell # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
1-1	95	no*	85	no	85	no	60	no
1-3	10	no	30	no	10	no	20	no
1-5	50	no	95	no	85	no	95	no
1-7	100	no	100	no	100	no	100	no
1-9	100	no	100	no	100	no	100	no
1-11	35	yes	65	yes	70	yes	30	yes
1-13	65	no	95	no	65	yes	60	no
1-15	80	no	25	yes	95	no	35	yes
1-17	45	yes	80	yes	35	yes	50	yes
1-19	90	no	70	yes	40	yes	50	yes
2-1	95	no	95	no	95	no	95	no
2-3	5	no	10	no	15	no	60	no
2-5	35	no	80	no	90	no	100	no
2-7	100	no	100	no	100	no	100	no
2-9	55	yes	50	yes	100	no	65	yes
2-11	95	no	95	no	80	no	90	no
2-13	90	yes	35	yes	90	no	85	no
2-15	45	yes	35	yes	40	yes	30	yes
2-17	85	no	90	no	70	no	80	yes
2-19	30	yes	35	yes	5	yes	40	yes
2-21	55	yes	75	no	80	no	100	no
3-1	90	no	65	no	80	no	90	no
3-3	40	yes	95	no	90	no	85	no
3-5	100	no	95	no	95	no	90	no
3-7	100	no	100	no	100	no	100	no
3-9	90	no	35	yes	95	no	85	yes
3-11	75	yes	80	yes	40	yes	65	yes
3-13	85	yes	40	no	40	yes	40	no
3-15	15	no	10	no	5	no	5	no
3-17	15	yes	25	yes	30	no	65	no

* "no" indicates that elk trails were visibly absent within the cell and "yes" indicates that elk trails were visibly present within the cell.

PHOTO #	Cell # 1		Cell # 2		Cell # 3		Cell # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
3-19	30	yes	35	yes	40	yes	40	yes
3-21	65	yes	85	no	90	no	75	no
3-23	95	no	95	no	95	no	95	no
4-1	5	no	10	no	10	no	10	no
4-3	10	yes	5	no	50	yes	5	yes
4-5	5	no	5	no	35	yes	10	no
4-7	10	yes	50	yes	50	no	85	no
4-9	70	yes	80	no	90	no	90	no
4-11	70	no	85	no	85	no	100	no
4-13	90	no	60	no	100	no	90	no
4-15	95	no	90	yes	65	yes	60	yes
4-17	80	yes	70	no	35	yes	30	no
4-19	95	no	95	no	45	yes	70	no
4-21	100	no	95	no	100	no	100	no
4-23	45	yes	50	yes	80	yes	65	no
4-25	20	yes	65	no	30	no	15	no
4-27	15	no	25	no	30	no	65	yes
4-29	75	yes	75	no	75	yes	85	no
4-31	100	no	90	no	100	no	100	no
5-1	95	no	25	no	60	no	55	no
5-3	10	no	15	no	15	no	15	no
5-5	15	no	20	yes	5	no	5	no
5-7	30	yes	50	yes	20	yes	65	yes
5-9	75	yes	75	yes	85	no	95	no
5-11	75	no	80	no	75	no	85	no
5-13	100	no	100	no	95	no	70	no
5-15	95	no	95	no	55	no	65	yes
5-17	30	yes	10	yes	30	yes	0	no
5-19	25	no	25	yes	0	no	5	yes
5-21	20	no	25	yes	10	yes	55	yes
5-23	60	no	100	no	85	no	90	no
5-25	100	no	95	no	95	no	95	no

PHOTO #	Cell # 1		Cell # 2		Cell # 3		Cell # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
5-27	70	yes	80	no	75	no	45	yes
5-29	5	no	5	no	30	yes	50	no
5-31	65	yes	80	no	70	no	75	no
5-33	75	no	90	no	65	no	70	no
5-35	100	no	95	no	100	no	90	no
6-1	65	yes	70	yes	40	yes	40	no
6-3	30	yes	0	no	30	no	5	no
6-5	5	no	10	yes	5	no	35	no
6-7	60	no	75	no	70	no	70	no
6-9	90	no	85	no	65	no	40	yes
6-11	90	yes	60	yes	65	yes	65	yes
6-13	60	yes	65	yes	70	yes	45	yes
6-15	45	yes	40	yes	45	yes	10	no
6-17	50	yes	65	yes	45	yes	65	no
6-19	35	yes	70	no	90	no	90	no
6-21	100	no	95	no	95	no	70	yes
6-23	30	yes	50	no	65	no	85	no
7-1	30	yes	60	no	15	no	60	no
7-3	35	no	20	no	15	no	10	no
7-5	0	no	0	no	0	no	0	no
7-7	5	no	10	no	15	no	15	no
7-9	25	no	40	no	5	no	10	no
7-11	30	no	30	no	0	no	0	no
7-13	20	no	20	no	5	no	5	no
7-15	30	yes	20	no	10	yes	5	no
7-17	30	no	25	no	10	no	20	no
7-19	70	yes	65	yes	65	yes	50	no
7-21	85	yes	80	yes	50	yes	60	yes
7-23	50	yes	95	no	95	no	100	no

1986 PHOTOGRAPHY
ELK TRAIL SAMPLING

PHOTO #	CELL # 1		CELL # 2		CELL # 3		CELL # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
1-3	95	no*	90	no	15	no	30	no
1-5	95	no	45	yes	95	no	70	yes
1-7	25	yes	25	no	20	no	25	yes
1-9	30	yes	40	yes	15	yes	35	yes
2-1	95	no	65	yes	100	no	100	yes
2-3	75	yes	55	no	75	no	70	no
2-5	95	no	40	yes	90	no	50	no
2-7	10	yes	20	yes	20	yes	15	yes
2-9	70	yes	70	yes	60	yes	85	yes
3-1	75	yes	10	yes	85	yes	55	yes
3-3	50	no	50	no	60	no	70	no
3-5	55	no	40	yes	5	no	5	no
3-7	25	yes	50	yes	30	yes	50	yes
4E-1	100	no	95	no	100	no	95	no
4E-3	35	yes	75	yes	30	yes	80	yes
4E-5	25	yes	50	yes	40	yes	85	yes
4E-7	90	no	85	no	80	yes	70	yes
4E-9	25	yes	40	yes	25	yes	30	yes
4E-11	95	no	100	no	90	no	90	no
4W-1	90	no	45	yes	100	no	70	yes
4W-3	40	yes	40	yes	15	yes	10	yes
4W-5	45	yes	40	yes	5	yes	10	yes
4W-7	70	yes	75	no	35	yes	40	yes
4W-9	95	no	100	no	95	no	100	no
5E-1	95	no	75	yes	100	no	90	no
5E-3	50	yes	70	no	35	yes	50	yes
5E-5	95	no	95	no	70	yes	85	no
5E-7	85	no	30	no	90	no	50	no
5E-9	35	no	75	no	10	no	30	yes
5E-11	70	yes	50	yes	65	yes	40	yes
5E-13	5	yes	30	yes	5	yes	35	yes
5E-15	80	no	100	no	50	yes	90	yes

* "no" indicates that elk trails were visibly absent within the cell and "yes" indicates that elk trails were visibly present within the cell.

1986 PHOTOGRAPHY
ELK TRAIL SAMPLING

PHOTO #	CELL # 1		CELL # 2		CELL # 3		CELL # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
5ERF-1	100	no	95	no	100	no	65	yes
5ERF-3	100	no	100	no	95	no	100	no
5ERF-5	90	no	90	no	100	no	95	no
5ERF-7	45	yes	40	yes	70	yes	40	yes
5ERF-9	65	yes	90	no	55	yes	65	yes
5ERF-11	65	no	60	yes	95	no	55	yes
5ERF-13	30	yes	50	yes	40	yes	65	yes
5W-1	75	yes	60	yes	45	yes	15	yes
5W-3	30	yes	20	yes	0	no	10	no
5W-5	10	yes	75	yes	20	yes	40	yes
5W-7	70	no	40	no	70	yes	50	yes
5W-9	70	no	100	no	95	no	100	no
6E-1	100	no	100	no	100	no	100	no
6E-3	80	yes	20	yes	95	no	75	yes
6E-5	65	yes	75	yes	50	yes	75	yes
6E-7	90	no	95	no	85	no	80	no
6E-9	30	no	5	no	10	no	0	no
6E-11	20	no	50	yes	10	yes	25	no
6E-13	15	yes	5	yes	35	yes	40	yes
6E-15	55	yes	65	yes	25	yes	60	yes
6W-1	90	no	35	yes	65	yes	30	no
6W-3	10	no	10	no	0	no	10	no
6W-5	5	no	5	no	15	no	30	no
6W-7	20	no	30	yes	5	no	5	no
6W-9	20	yes	30	yes	15	yes	45	yes
7E-1	65	yes	75	no	90	no	80	yes
7E-3	65	yes	15	yes	15	yes	15	yes
7E-5	45	yes	35	yes	15	yes	30	yes
7E-7	60	no	60	no	20	no	55	no
7W-1	45	no	35	no	80	no	40	no
7W-3	40	no	15	no	10	no	15	no
7W-5	40	yes	55	yes	30	yes	30	yes
7W-7	5	yes	15	yes	20	yes	50	yes
7W-9	10	yes	30	yes	20	yes	35	yes
7W-11	65	yes	90	no	95	no	90	no

1986 PHOTOGRAPHY
ELK TRAIL SAMPLING

PHOTO #	CELL # 1		CELL # 2		CELL # 3		CELL # 4	
	%cover	trails	%cover	trails	%cover	trails	%cover	trails
8E-1	80	yes	80	yes	50	yes	70	yes
8E-3	15	yes	5	yes	35	yes	0	yes
8E-5	0	no	5	yes	0	no	10	no
8E-7	20	yes	50	yes	45	no	80	no
8E-9	90	no	100	no	45	no	90	no
8W-1	70	no	60	yes	25	no	70	no
8W-3	15	no	15	no	15	no	20	no
8W-5	0	no	5	no	5	no	5	no
8W-7	40	yes	85	yes	85	yes	100	no
9E-1	45	no	35	no	50	no	35	no
9E-3	5	no	5	no	5	no	0	no
9E-5	5	no	40	no	0	no	0	no
9E-7	55	no	45	no	15	no	25	no
9E-9	35	no	30	no	40	no	35	no
9W-1	5	no	50	no	0	no	10	no
9W-3	5	no	5	no	30	no	0	no
9W-5	0	no	0	no	0	no	0	no
9W-7	45	yes	75	no	40	no	20	no

APPENDIX VII

Flight Planning Specifications and Procedures

FLIGHT PLAN SPECIFICATIONS

LOCATION: Northeast part of Mount Rainier National Park, Washington

FILM TYPE: Natural Color negatives/prints

CAMERA FOCAL LENGTH: 12" (304.8mm)

NEGATIVE FORMAT: 9" x 9" (228.6mm x 228.6mm)

DESIRED NEGATIVE SCALE: 1:5,000

ENDLAP: 60%

SIDELAP: 30%

SCALE OF BASEMAP: 1:50,000

AVERAGE TERRAIN ELEVATION: 5,850' above sea level

FLYING HEIGHT ABOVE TERRAIN: 5,000'

FLYING HEIGHT ABOVE SEA LEVEL: 10,850'

SIDE TO SIDE COVERAGE PER PHOTO: 1,143m x 1,143m on ground
22.86mm x 22.86mm on map

DISTANCE BETWEEN FLIGHT LINES: 800.1m on ground
16.00mm on map

NUMBER OF FLIGHT LINES: Seven lines (Two long, Five short)

WIDTH OF STUDY AREA (North/South): 4,800.6m on ground
96.012mm on map

DISTANCE BETWEEN PHOTO CENTERS: 457.2m on ground
9.144mm on map

NUMBER OF PHOTOS ON TWO LONG LINES: 35 Photos

NUMBER OF PHOTOS ON FIVE SHORT LINES: 21 Photos

LENGTH OF TWO LONG LINES: 15,544.8m on ground
310.90mm on map

LENGTH OF FIVE SHORT LINES: 9,144.0m on ground
182.88mm on map

ESTIMATE OF TOTAL NUMBER OF PHOTOS: 175 Photos

DESIRED FLIGHT DATE(S): Mid-August, 1985

Flight map computations

Items to be computed in preparing the flight plan are:

Flying height above ground datum: Height = focal length × scale denominator, or

$$H = 0.153 \text{ m} \times 25{,}000 = 3{,}825 \text{ m}$$

Flying height above mean sea level:

$$3{,}825 + 500 = 4{,}325 \text{ m}$$

Direction of flight lines: North-south, following long dimension of tract.

Number of flight lines: Assuming an average sidelap of 30 percent, the lateral gain from one line to another is 70 percent of the negative format (on the ground) or 0.70 × 5,750 = 4,025 m between lines. The number of *intervals* between lines is found by division of the tract width (20 km or 20,000 m) by 4,025. The result is 4.97 or 5 *intervals* and 6 *flight lines.*

Actual (adjusted) ground distance between flight lines: Tract width (20,000 m) ÷ 5 intervals = 4,000 m between lines.

Actual (adjusted) percentage of sidelap:

$$\text{Sidelap percentage} = \frac{\text{Negative width (m)} - \text{Spacing (m)}}{\text{Negative width (m)}} (100)$$

$$\text{Sidelap percentage} = \frac{5{,}750 - 4{,}000}{5{,}750} (100) = 30.4\%$$

Map distance between flight lines (map scale is 500 m/cm):

$$\frac{1 \text{ cm}}{500 \text{ m}} = \frac{X \text{ cm}}{4{,}000 \text{ m}}; \; X = 8.00 \text{ cm between lines on map}$$

Ground distance between exposures on each line: Assuming an average forward overlap of 60 percent, the spacing between successive exposures is 40 percent of the negative format (on the ground), or 0.40 × 5,750 = 2,300 m between exposures.

Map distance between exposures on each line:

$$\frac{1 \text{ cm}}{500 \text{ m}} = \frac{X \text{ cm}}{2{,}300 \text{ m}}; \; X = 4.60 \text{ cm between exposure centers on map}$$

Number of exposures on each line: Number of *intervals* between exposures is found by division of tract length (30 km or 30,000 m) by 2,300 = 13.04 *intervals.* This will require 14 exposures *inside* the area, assuming that the first exposure is centered over one tract boundary. In addition, 2 extra exposures are commonly made at the ends of each flight line; thus, a total of 14 + 2 + 2 = 18 *exposures* would be taken on each flight line.

Total number of exposures required to cover entire tract: 6 lines × 18 exposures per line = 108 exposures.

APPENDIX VIII

Aerial Photography Survey Companies

and

Aerial Film Processors

Directory of Aerial Photography Service Companies

The initial listing is given below. The directory is for foresters and others who are involved in aerial photography contracting or procurement. The directory should help people know who is out there and what areas they service. The directory hopefully will evolve into something more complete and will include specific equipment and services offered by those on the list. Again, if there are changes, (i.e. additions, deletions, etc.) that need to be made, please let me know.

Bill Steigerwaldt,
Chair, Operations Committee

Company Name	Contact	Street Address	City/State	Telephone No.
Abrams Aerial Survey Corporation	Carl Schafer	124 North Larch Street	Lansing, MI 48901	517/372-8100
Aerial Cartographics of America, Inc.	Charles Woodward	7000 Lake Ellenor Drive	Orlando, FL 32809	305/851-7880
Aerial Photo Service, Inc.	G. Moody	324 Main Mall	Tulsa, OK 74103	918/736-4011
Aero Service Corporation		8100 Westpark Drive	Houston, TX 77063	
Aero-Metric Engineering, Inc.	Bob Johanning	4708 North 40th Street	Sheboygan, WI 53081	414/457-3631
Aero-Science	Fred Ries	8787 East Mountain View	Scottsdale, AZ 85258	602/948-6634
Aeroeco, Inc.	Bob Macomber	232 Cardamon Drive	Edgewater, MD 21037	301/261-8448
Aerographics	Ron Welebny	1575 Smithtown Avenue	Bohemia, NY 11716	516/589-6045
Air Photo Tech. Inc.		2013 Merrill Field Ave.	Anchorage, AK 99501	
Air Photographics, Inc.	John Houyoux	Route 4, Box 500	Martinsburg, WV 25401	304/263-6976
Air Survey & Design, Inc.		460 Spring Park Place	Herndon, VA 22070	703/437-6060
Air Surveys by Toler, Inc.		P.O. Box 459	Mineral Wells, TX 76067	
Airborne Data, Inc.		P.O. Box 6013	Daytona Beach, FL 32022	
Airborne Systems, Inc.		1891 Betmor Lane	Anaheim, CA 92805-6701	714/634-3002
American Aerial Surveys, Inc.		564 So. Stewart Drive	Covina, CA 91723	813/331-5304
American Aerial of No. Calif.	Roland Holmes	6249 Freeport Blvd.	Sacramento, CA 95822	916/422-0770
Atlantic Aerial Surveys, Inc.	Ray J. Meehan	803 Franklin Street, SE	Huntsville, AL 35801	206/536-6616
Bucher, Willis, Ratliff	Keith Lassen	609 West North Street	Salina, KS 67401	913/421-3465
CHM Hill		1525 Court Street	Redding, CA 96001	916/243-5831
Cartwright Aerial Surveys	Mr. Cartwright	Executive Airport	Sacramento, CA 95822	916/421-3465
Charles T. Main, Inc.		P.O. Box 240236	Charlotte, NC 28224	
Chicago Aerial Surveys, Inc.		2140 Wolf Road	Des Plaines, IL 60018	312/298-1480
Civil Map Service, Inc.	Ronald Gority	5732-A Industry Lane	Frederick, MD 21701	301/695-6270
Col-East		Box 347, Harriman Airport	North Adams, MA 01247	413/664-6769
Continental Aerial Surveys		P.O. Box 300	Alcoa, TN 37701	
Danner Aerial Survey	Charles Danner	2406 E. University Ave.	Urbana, IL 61801	217/328-3434
Davidson Aerial Surveys	Pete Davidson	256 Pennsylvania Ave.	Louisville, KY 40206	502/897-0593
Dickerson Aerial Surveys, Inc.	Brian Dickerson	107 N. 10th Street	Lafayette, IN 47901	317/742-5092
Flightech, Inc.	Howard Langston	P.O. Box 1138	Clinton, MS 39056	601/924-6930
G.R.W. Aerial Surveys	Pete Davidson	801 Corporate Drive	Lexington, KY 40503	
Geodetic Services, Inc.	Duane C. Brown	1511 Hiverview Drive	Melbourne, FL 32901	305/724-6831
Great Basin Aerial Surveys	Maurice Lafferty	255 Glendale Ave.	Sparks, NV 89431	702/359-7242
Greiner Aerial Surveys	Paul Lawrence	6220-24th Street	Sacramento, CA 95822	916/391-1651
Gulf Coast Aerial Mapping Co., Inc.	C.R. Foster	4242 Harding Blvd.	Baton Rouge, LA 70807	504/355-9722
Hammon, Jensen, Wallen		8407 Edgewater Drive	Oakland, CA 94621	415/638-6122
Hansa Luftbild German Air Surveys		Elbestr. 5, P.O. Box 3609	D-4400 Munster, Fed. Repub. Germany	
Harris Aerial Surveys, Inc.	Ron Joyce	P.O. Box 246	Midway, AR 72651	501-481-5151
Henderson Aerial Surveys, Inc.		5125 W. Broad Street	Columbus, OH 43228	614/878-3925
Hogan and Olhvasen, Inc.		2300 W. Eisenhower Blvd.	Loveland, CO 80537	
Horizons, Inc.		6125 Blue Circle Drive	Minnetonka, MN 55343	612/931-9869
Horizons, Inc.		1635 Deadwood Ave.	Rapid City, SD 57709	605/343-0280
Hoskins-Western-Sonderegger		825 J Street	Lincoln, NE 68501	402/758-7212
I.K. Curtis Services, Inc.	Ivan K. Curtis	2907 Empire Ave.	Burbank, CA 91504	818/842-5127
International Aerial Mapping		8927 International Drive	San Antonio, TX 78216	512/826-8681
James W. Sewall Company	Roy Klitch	147 Centre Street	Old Town, ME 04468	207/827-4456
Kasper Aerial Surveys	Maan-Nam Liu	24 Stony Hill Road	Bethel, CT 06801	203/748-2623
Kenting Earth Sciences, Ltd.		380 Hunt Club Road	Ottawa, Ontario K1G 3N3	Canada
Keystone Aerial Surveys, Inc.	Al Gardner	P.O. Box 21059	Philadelphia, PA 19114	215/677-3119
Kucera International, Inc.	John Antalavich	7000 Reynolds Road	Mentor, OH 44060	216/255-4700
M.J. Harden Associates, Inc.		1019 Admiral Blvd.	Kansas City, MO 64106	
MARKHURD Aerial Surveys, Inc.	Marshall Swenson	345 Pennsylvania Ave. S.	Minneapolis, MN 55426	612/545-2583
Michael Baker Corporation		4301 Dutch Ridge Road	Beaver, PA 15009	
North Pacific Aerial Surveys, Inc.	Roger Carter	4241 "B" Street	Anchorage, AK 99503	907/563-3038
North West Survey Geographic Services		17203-103 Ave.	Edmonton, Alberta T5S 1J4	Canada
Orhan's Reproductions & Photomapping		2616-18th Street, N.E.	Calgary, Alberta T2P 1L3	Canada
Pacific Aerial Surveys	Mike Renslow	444 Pendleton Way	Oakland, CA 94621	
Pacific Aerographics	Andy Andelin	425 E. Columbine	Santa Ana, CA 92707	714/545-3497
Park Aerial Surveys, Inc.	J.K. Sciberras	P.O. Box 17408	Louisville, KY 40217	502/366-4571
Photo Science, Inc.		7840 Airpark Road	Gaithersburg, MD 20879	
Photogrammetric Consultant, Inc.	John Kenefick	P.O. Box 3556	Indialantic, FL 32903	305/725-2715
Piedmont Aerial Surveys, Inc.	Irving Isaacson	123 S. Walnut Circle	Greensboro, NC 27409	803/294-6025
Quinn Associates, Inc.	A.O. Quinn	460 Caredean Drive	Horsham, PA 19044	215/674-0545
R.J. Krawietz		434 Yosemite Drive	San Antonio, TX 78232	512/494-5156
R.M. Keddal and Associates, Inc.	Robert Keddal	1900 Sleepy Hollow Road	Library, PA 15129	412/563-1744
Radman Aerial Surveys	Daniel Radman	6220 24th Street	Sacramento, CA 95822	916/391-1651
Rainer Aerial Surveys		P.O. Box 29	Olympia, WA 98507	
Reids Aerial Mapping	Bob Reid	1580 Chester Street	Aurora, CO 80010	303/361-6150
Remote Sensing Services, Ltd.		3804 W. Oak Avenue	McHenry, IL 60050	815/385-2412
Robinson Aerial Surveys, Inc.	Gary Scocco	43 Sports Avenue	Newton, NJ 07860	201/383-2511
San-Lo Aerial Surveys		4875 Viewridge Avenue	San Diego, CA 92123	619/565-1024
Scharf and Associates, Inc.	Billy Youngblood	470 S. Colorado Blvd.	Denver, CO 80222	303/366-0951
Steigerwaldt Land Services, Inc.	Wm. Steigerwaldt	622 Business Hwy., 51 S.	Tomahawk, WI 54487	715/453-3274
Surdex Corporation	Earl Hoffmann	520 Spirit of St. Louis	Chesterfield, MO 63017	314/532-3427
Swissair Photo and Surveys, Ltd.		P.O. Box 288	CH-8035 Zurich, Switzerland	
TerraFoto S.A.		833 04560 Brooklin	Sao Paulo, Brazil	
The Sidwell Company		28 W. 240 N. Ave.	West Chicago, IL 60185	
Tobin Surveys, Inc.		114 Camp St., Box 2101	San Antonio, TX 78297	
Tomasko Aerial Surveys, Inc.	Joe Tomasko	3200 Hillside Ave., #15	Birmingham, AL 35205	205/323-5955
Trident Arctic Exploration Ltd.		401-9th Avenue S.W.	Calgary, Alberta T2P 3C5	403/262-4499
United Aerial Mapping		5411 Jackson Drive	San Antonio, TX 78238	512/684-2147
Valley Air Photos	Richard Graville	P.O. Box 1118	Caldwell, ID 83606	208/454-1344
Vernon Graphics, Inc.		400 Executive Blvd.	Elmsford, NY 10523	
W.A.C. Corporation	Roy Bristow	520 Conger Street	Eugene, OR 97402	503/995-8600
Walker and Associates, Inc.	Al Wounker	6264 Stanely Ave., S.	Seattle, WA 98108	206/763-1497
Walker and Associates, Inc.	Jim Walker	640 Axminister Drive	Fenton, OH 63026	314/343-6111
Western Aerial Photos		303 Convention Way	Redwood City, CA 94063	415/369-5273
Western State Aerial Surveys		P.O. Box 478	Gunnison, CO 81230	303/641-2996
Williams-Stackhouse Inc.		2118 Mannix Drive	San Antonio, TX 78217	
Woolpert Consultants		2324 Stanley Avenue	Dayton, OH 45404	513/461-5660

Compiled from the August 1986 Directory Issue of Photogrammetric Engineering and Remote Sensing, from subsequent ASPRS issues and advertising, from correspondence with the U.S.G.S. Washington, DC. No endorsement of any company is intended.

Directory of Aerial Film Processors
Black and White, Color or Color Infrared Films

Has Images Inc.
136 North St. Clair Street
Suite 300
Dayton, OH 45402
Contact: Mr. Harry A. Stiller
Phone: (513) 222-3856

Photo Science, Inc.
7840 Airpark Road
Gaithersburg, MD 20879
Contact: Mr. Richard Crouse, Jr.
Phone: (301) 948-8550

Rocky Mountain Film Laboratory
145 Madison Street
Denver, CO 80206
Contact: Unknown at present.

I.K. Curtis Services, Inc.
2907 Empire Avenue
Burbank, CA 91504
Contact: Mr. Tony Black
Phone: (818) 842-5127

W.A.C. Corporation
520 Conger Avenue
Eugene, OR 97402
Contact: Mr. Gordon Wilkinson
Phone: (503) 342-5169

Precision Photo Laboratories, Inc.
5758 North Webster Street
P.O. Box 14595
Dayton, OH 45414
Contact: Mr. Bob Rolfe
Phone: (513) 898-7450

Criterion Photoworks
119 East 4th
P.O. Box 292
Minden, NE 68959
Phone: (308) 832-2100

These laboratories also possess KODAK VERSAMAT Film Processors for developing KODAK Black and White Aerial Films. Therefore, each facility can meet all your aerial film processing needs--black and white or color in all format sizes from 35mm to 9-1/2 inch widths. Contact the persons listed above for specific information on costs, delivery, etc.

Note that Eastman Kodak Company does not offer Process EA-5, the Aero-Neg Color Process, or black and white processing for Kodak Aerial Films. Also, Process E-4 was discontinued by Kodak Processing Lab in May 1985. For a list of commercial laboratories offering Process E-4, write to: **Photo Information Dept., Eastman Kodak Company, Rochester, NY 14650.**

Environmental Remote Sensing
Applications Laboratory
Oregon State University
Corvallis, OR 97331-6703