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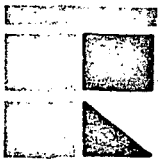

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ERT Doc. P-407-4

15 March 1973

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attention: Dr. Vincent V. Salomonson
ERTS Scientific Monitor, Code 651

Subject: ERTS-A Investigation No. SR201: Evaluate the Application of ERTS-A Data for Detecting and Mapping Snow Cover

Principal Investigator: James C. Barnes, PR011

Gentlemen:

This is the third bimonthly Type I Progress Report describing work performed by Environmental Research & Technology, Inc. (ERT), for the National Aeronautics and Space Administration under Contract No. NAS 5-21803. This report covers the period from 31 December 1972 to 28 February 1973.

The purpose of this investigation is to evaluate the application of imagery from the ERTS-A RBV and MSS sensors for snow survey. The objectives are: to determine the spectral interval most suitable for snow detection and mapping; to determine the accuracy with which snow lines can be mapped in comparison with the accuracies attainable from other types of measurements; and to develop techniques to differentiate reliably between snow and clouds, to attain accurate geographic referencing, and to understand the effects of terrain and forest cover on snow detection. The results will demonstrate the advantages and limitations of spacecraft high-resolution, multispectral measurements for snow survey and will provide the analyst with interpretive techniques that will enable the maximum use of data from ERTS and future spacecraft systems.

A. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Sample

The total ERTS-1 data sample received through this reporting period comprises some 100 usable passes crossing the upper midwest and western parts of the country. The quality of the positive prints continues to be good overall, although occasional scenes appear to be either under or over-exposed. The majority of the 70 mm negatives in the total data sample are

usable with standard photographic equipment; the problem experienced early in the contract period, when the negatives were of a density that made them very difficult to work with, appears to have been corrected. The number of passes for each geographic area in which cloud-free conditions exist and snow can be identified is given in Table 1.

TABLE 1

SUMMARY OF DATA SAMPLES

Geographic Area	No. of Passes	Period of Coverage
Olympic Mountains (Washington)	6	25 July - 26 January 1973
Lower Columbia Basin (Washington, Oregon)	11	28 July - 23 January 1973
Canadian Rockies (British Columbia)	1	27 July 1972
Upper Columbia Basin (Idaho, Montana, Wyoming, Nevada)	26	27 Aug 1972 - 01 Feb 1973
Sierra Nevada (California, Western Nevada)	12	25 July 1972 - 20 Jan 1973
Salt-Verde Watershed (Arizona)	6	21 Nov 1972 - 01 Feb 1973
Upper Mississippi-Missouri River Basin Area	38	24 Nov 1972 - 10 Feb 1973
(Total number of useful passes =	100)	

2. Correlative Data

Correlative snow data have been requested through the National Weather Service, Office of Hydrology. The data include Climatological Data Summaries (by State), Snow Survey Data, Snowline Elevation Data, and the Weekly Weather and Crop Bulletin. Late in the reporting period, a part of these data was received directly from the Office of Hydrology. The snowline elevation information will be obtained through direct contact with the appropriate River Forecast Centers in Portland and Sacramento. Additional aerial survey snow charts for the Salt-Verde Watershed in Arizona have also been received from the Salt River Project Office. Aerial surveys of the Watershed are flown at least biweekly throughout the snow season.

3. Aircraft Data

We were informed early in the reporting period that U-2 flights in support of the ERTS mission would be flown over two test sites specified in this study in late February or early March. The two sites are the southern Sierras and the Salt-Verde Watershed. Data from the on-board RBV sensor were to be collected as the plane crossed each of the snow-covered mountain ranges. At this time, we do not know whether the planned flights have taken place; if successful flights are made, these aircraft data will then be analyzed in conjunction with the corresponding ERTS imagery, hopefully collected within a few days of the U-2 flight.

4. Results of Analyses

The analysis of the ERTS data is continuing using the procedures described in the previous report ("Use of ERTS Data for Mapping Snow Cover in the Western United States," Type II Report, February 1973). A sufficient amount of data has now been received to permit analyses of the southern Sierras to be undertaken. This geographic area was defined as one of the prime test sites in the study. For the Salt-Verde Watershed, a January case has been analyzed, in addition to the November case described in the previous report.

- Southern Sierras

The test site in the southern Sierras comprises four river basins: the Kings, Kaweah, Tule, and Kern. An overlay of the basin boundaries has been prepared at a 1:1 million scale, through reference to the California Snow Survey Index Map and the Office of Hydrology San Joaquin and Kern River Basins Drainage Map. Two elevation contours, the 5000 ft (1525 m) and 10,000 ft (3050 m), have been drawn on the transparent overlay. Using the overlay, the snow extent is being mapped for six dates: 16 September, 21 October, 26 November, 14 December, 2 January and 20 January. The elevation of the snowline for each basin as mapped from the ERTS imagery will then be determined for each date.

- Salt-Verde Watershed

The snow extent in the Salt-Verde Watershed has been mapped using the MSS-5 image from 14 January. An aerial survey snow chart for a part of the area was available for 12 January, just two days prior to the ERTS coverage. Maps showing the ERTS and aerial survey snowlines for the November case, discussed in the previous progress report, and the recently analyzed January case, are given in Figures 1 and 2. Snow monitoring is of particular interest this season in the Salt-Verde Watershed, as the snowpack at the end of February contained 200 to 250% normal water content. At that time, snow depths south of Flagstaff were as much as four feet.

In both cases, the agreement between the ERTS and aerial survey data is good, especially in the northern part of the watershed, north of about 34°30'N. The comparative maps show that the satellite snowline is more detailed than the aerial survey snowline; also, in most areas the snow extent mapped from ERTS is slightly less than that indicated on the survey charts. In discussions with the watershed specialist who conducts many of the aerial surveys, he related that the observer often views the snowline at an angle from as much as 10 miles away and customarily "smooths" the observed snowline. Thus, he believes that the snowline mapped from ERTS data may, in fact, be more accurate than that depicted on the aerial survey charts.

The agreement is not as good in the eastern part of the watershed, east of about 111°W. In the November case, however, the snow amounts in this area are comparatively light and considerable snowmelt could have occurred during the 7-day interval between the aerial survey and the ERTS pass. In fact, the watershed specialist reports that the area near 34°N, 111°W, where the ERTS data show only a limited snow extent compared to that indicated on the aerial survey chart, is mesa land. In this type of terrain, it is common for snow to melt rapidly. Since the aerial survey chart indicates a snow depth of only a trace to 1" over much of the area on 14 November, it is quite likely that a week later the snow would be confined to the higher elevations, as the ERTS data indicate. In the January case, a direct comparison is not possible because the survey flight did not cross the eastern part of the watershed (also, the area near 34°N, 111°W discussed above was on the edge of the scene in the 14 January ERTS images).

A separate discussion of significant results and their relationship to practical applications or operational problems, including estimates of the cost benefits of any significant results, is attached to this progress report.

5. ERTS-1 Symposium

During this reporting period, a paper was prepared for presentation at the ERTS-1 Symposium, held at the Sheraton Motor Inn, 5-9 March. The paper, entitled "Use of ERTS Data for Mapping Snow Cover in the Western United States," describes the results obtained under the subject contract through mid-February. The Symposium also provided an opportunity for contact with other investigators working in the same discipline and/or geographic areas.

B. PLANS FOR NEXT REPORTING PERIOD

Analysis of data for the specified mountainous areas in the western United States will be continued. During the next reporting period, emphasis will be on the Salt-Verde Watershed and Southern Sierras areas. The Salt-Verde Watershed is an area of particular interest at this time, because of the unusually heavy snowpack that has accumulated during this winter season.

Furthermore, neither of these areas is included as a test site in any other current ERTS investigation related to the water resources discipline. Further extensive analysis of the Cascades area is not planned; the Cascades was not specified as a primary test site in this investigation, but was examined because snow cover existed in the area during the early period of ERTS operation. Sufficient data have now been received over the more southern areas, and it is assumed that ERTS coverage will continue through the late winter and spring snowmelt seasons.

Additional correlative snow data will be accumulated. The most useful data so far are the aerial survey charts received from the Salt River Project Office. As the snowmelt season approaches, similar charts will become available for the river basins of the southern Sierras. Any other useful data that can be supplied through the River Forecast Centers, such as specific snowline elevation measurements and snow course measurements, will also be acquired. It is further anticipated that the data collected by the U-2 flights flown over the southern Sierras and the Salt-Verde Watershed in support of the ERTS mission will soon be available.

In the analysis of the southern Sierras river basins, methods for correctly interpreting snow cover in forested areas and in areas of shadows caused by north-facing slopes will be investigated. The initial analysis of the mid-winter ERTS imagery in this area indicates that mountain shadows may be a more significant problem during winter than they were in the imagery examined previously taken during the time of higher sun angle. The correct interpretation of these effects will be essential for machine processing of ERTS data for snow mapping purposes. The snowline will also be mapped carefully to investigate whether significant differences exist between the snowline elevation determined through direct comparison with elevation contour charts and the "equivalent snowline altitude" derived from mapping the snow extent and relating the snow-covered area to the area-altitude function for the particular river basin. In a previous study of the southern Sierras using meteorological satellite data, equivalent snowline elevations were derived for the Kings River Basin (Barnes and Bowley, 1970: "The Use of Environmental Satellite Data for Mapping Annual Snow-Extent Decrease in the Western United States," Final Report for NOAA/NESS under Contract No. E-252-69(N)).

Analysis of data covering the relatively flatter terrain of the Upper Mississippi-Missouri River Basins region will also be undertaken during the next reporting period. The data from this region will present an opportunity to investigate the differences in snow reflectance in forested and non-forested areas and the differences in reflectance as snow amounts increase from a no-snow situation to depths of several inches or more. Initial examination of these data indicates that the Black Hills area may be especially useful for investigating forest effects, because of the well-defined boundaries between heavily forested land and the surrounding non-forested land.

C. PROBLEMS

No problems to impede the progress of the investigation are anticipated.

D. ERTS IMAGE DESCRIPTION FORMS

Image Descriptor Forms are attached to this progress report.

E. FUNDS

It is anticipated that the remaining funds will be adequate for successful completion of the investigation.

Very truly yours,

James C. Barnes

James C. Barnes
Principal Investigator

JCB:jm

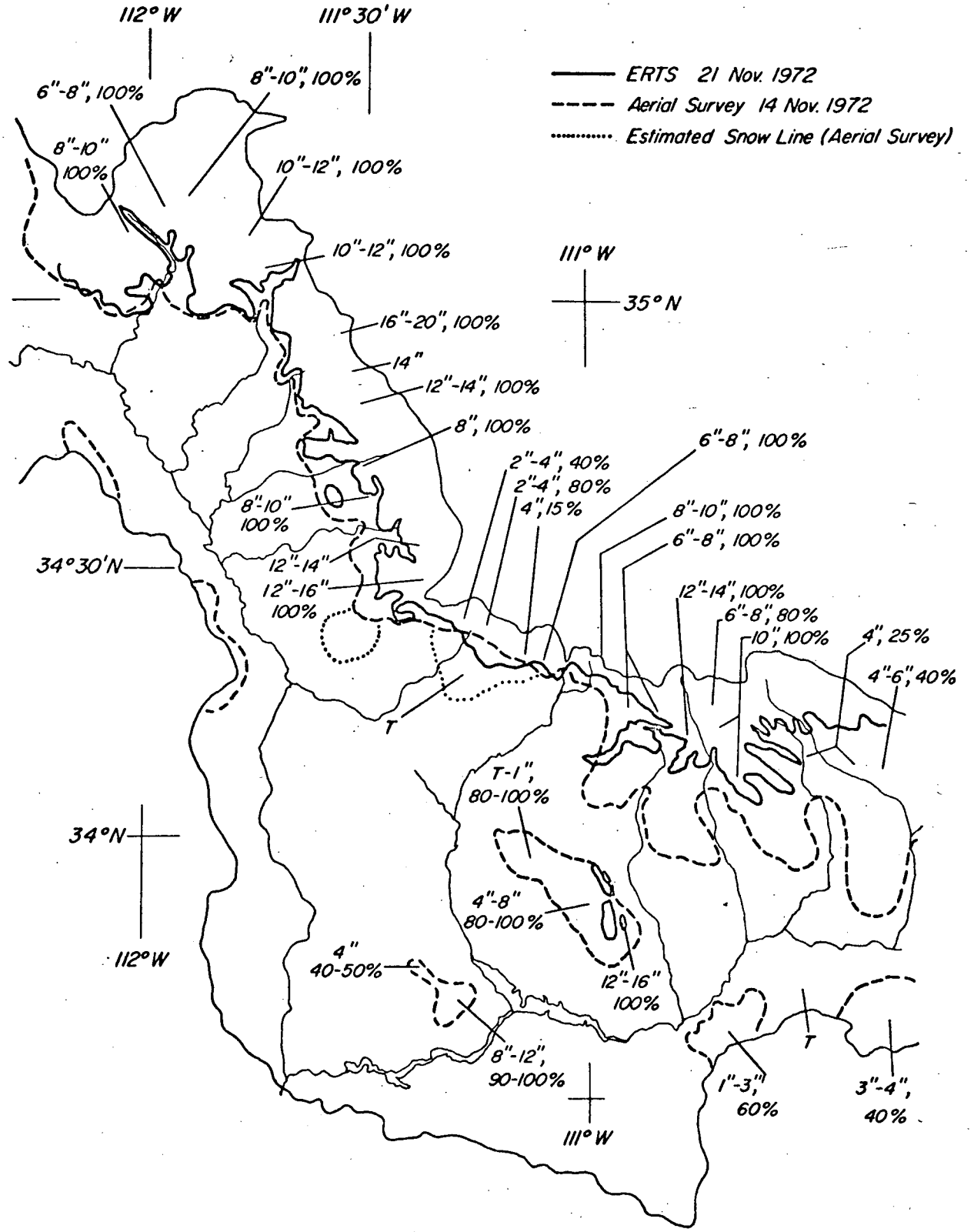

Figure 1 Comparison between snowline mapped from ERTS MSS-5 image and that depicted on aerial survey snow chart, Salt-Verde Watershed, Arizona, November 1972.

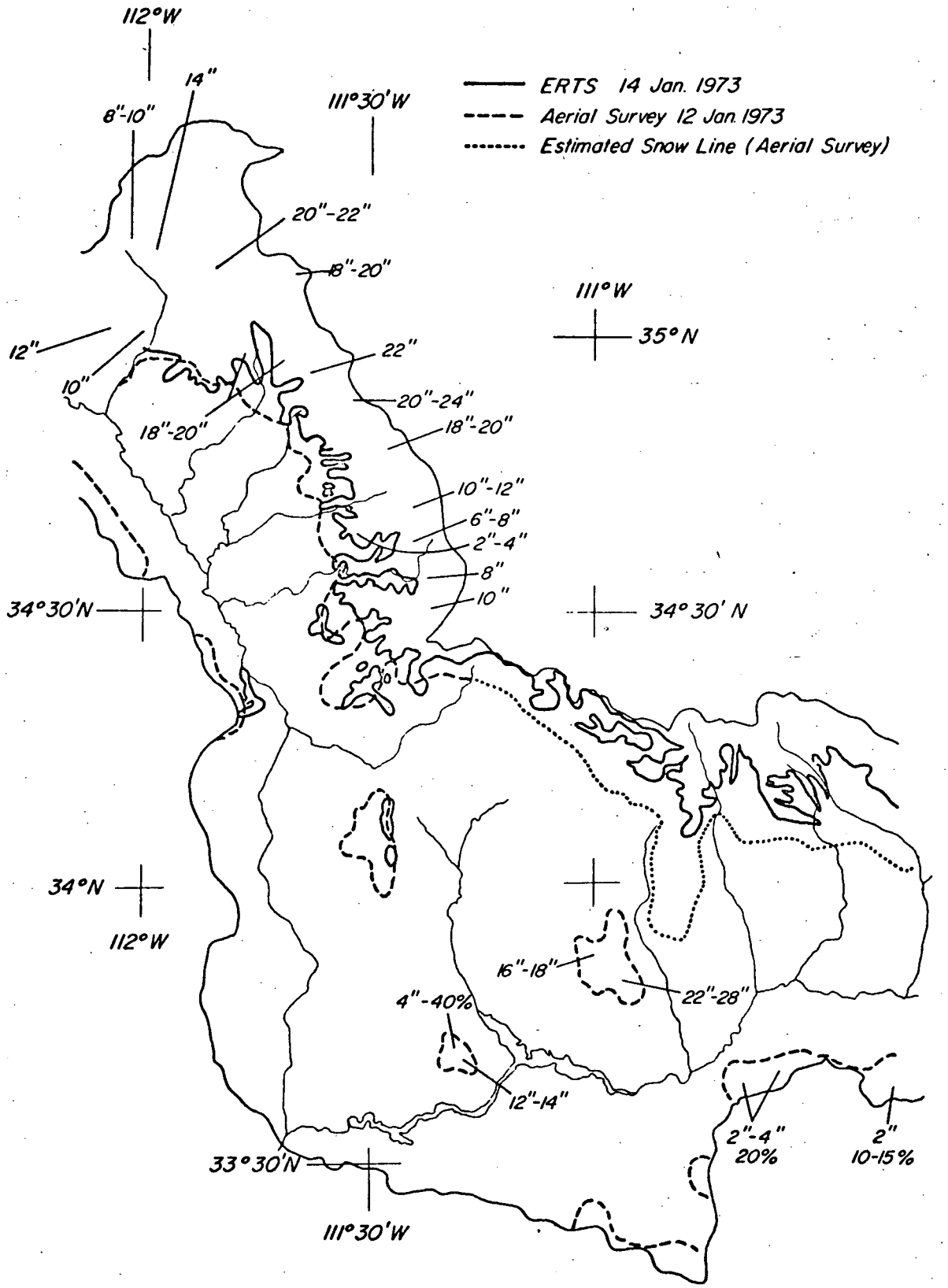

Figure 2 Comparison between snowline mapped from ERTS MSS-5 image and that depicted on aerial survey snow chart, Salt-Verde Watershed, Arizona, January 1973.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
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ID

DATE 15 March 1973

PRINCIPAL INVESTIGATOR Mr. James C. Barnes

USER ID
~~GSFC~~ P011

ORGANIZATION Environmental Research & Technology, Inc.

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Snow Pack	Mtns.	Rivers	
1055-18055 MP	X	X	X	Lakes, Agriculture, City, Conifer
1055-18062 MP	X	X	X	Cities, Urban Areas, Valley, Highways, Agriculture
1121-17330 MP	X	X	X	Clearings (powerlines), Lakes, Meteor Crater
1136-17130 MP			X	Snow, Conifer
1136-17121 MP			X	Snow, Lake, Ice, Dam, Agriculture
1168-16485 MP			X	Snow, Smoke Plumes, Conifer, Agriculture, Lakes, Ice, Highways
1181-18065 MP	X	X	X	Cities, Urban Areas, Valley, Highways, Agriculture, Cirrus, Smoke
1186-18321 MP	X	X	X	Cities, Bays, Orographic Clouds, Cirrus, Cumulus
1187-18380 MP	X	X	X	Coastline, Sediment, Cirrus, Clearing (Powerline), Bays, Islands
1189-17055 MP			X	Lakes, Ice, Cities, Urban Areas, Agriculture, Highways
1189-17061 MP			X	Lakes, Ice, Conifer, Agriculture, Dam

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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GSFC 37-2 (7/72)

DISCIPLINE: WATER RESOURCES, SNOW SURVEYS

TITLE: EVALUATE THE APPLICATION OF ERTS-A DATA FOR DETECTING AND MAPPING SNOW COVER (SRNo. 201)

PRINCIPAL INVESTIGATOR: James C. Barnes (PR011)
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DISCUSSION OF SIGNIFICANT RESULTS:

The results of the analysis of ERTS-1 data covering the specified test sites in the western United States indicate that the MSS-4 and MSS-5 spectral bands are the most useful for detecting and mapping snow cover. Of these two bands, the MSS-5 is the most consistently useful, as snow-covered areas in some MSS-4 images are nearly saturated causing some loss of detail. Snow can be readily detected and can be distinguished from clouds through a number of interpretive keys. At the ERTS resolution, numerous terrestrial features not visible in lower resolution meteorological satellite data can be detected. In addition to various natural features, man-made features such as roads, electric power lines, cultivated fields, and timber cuts are visible.

In four mountain areas for which data have been analyzed on at least two different dates, changes in snowline elevation ranging from 200 to as much as 4000 ft have been mapped. In these analyses topographic charts of a scale of 1:250,000 have been found to be useful for measuring snowline elevation. In two cases analyzed for the Salt-Verde Watershed in Arizona, good agreement is observed between the location of the snowline as mapped from the ERTS data and as depicted on aerial snow survey charts compiled within a few days of the ERTS passage. In fact, the results indicate that the snowline can be mapped in more detail from the ERTS imagery than can be achieved by current aerial survey methods. Moreover, the flight time

required to survey the Salt-Verde Watershed is about five hours, with an additional hour or so required to complete preparation of the chart. On the other hand, an experienced analyst can map the entire watershed from the ERTS imagery within about two hours. Eventual machine processing will be even faster. Thus, it appears that snow extent in an area such as the Salt-Verde Watershed can be mapped from ERTS data on a cost-effective basis.