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FEASIBILITY STUDY FOR LOCATING ARCHAEOLOGICAL VILLAGE SITES

BY SATELLITE REMOTE SENSING TECHNIQUES

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Final Report for :
Contract NAS5-21833
ERTS Project 110-N
October 17, 1974

110 N

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MAR 65 1975

SIS/902.6

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Feasibility study for locating archaeological village sites by satellite remote sensing techniques		5. Report Date October 17, 1974
		6. Performing Organization Code
7. Author(s) W. J. Stringer, J. P. Cook		8. Performing Organization Report No.
9. Performing Organization Name and Address Geophysical Institute University of Alaska Fairbanks, Alaska 99701		10. Work Unit No.
		11. Contract or Grant No. NAS5-21833 Task 110-N
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771 Code Technical Monitor: Mr. Edward C. Crump, 430		13. Type of Report and Period Covered Type III-Final Report July 1972-January 1974
		14. Sponsoring Agency Code

15. Supplementary Notes

One of twelve ERTS-1 projects conducted by the University of Alaska
ERTS-1 Project GSFC No. 110-14
P.I. John P. Cook, GSFC I.D. No. UN 597

16. Abstract

The objective of this project was to determine the feasibility of detecting large Alaskan archaeological village sites by satellite remote sensing techniques. The approach used was to develop digital multispectral signatures of dominant surface categories including vegetation types, exposed soils and rock, hydrological patterns and known archaeological sites. ERTS scenes were then printed out digitally in a map-like array with a letter reflecting the most appropriate classification representing each pixel.

During the first 6-months period, preliminary signatures were developed and tested. It was determined that there was a need to improve archaeological site identification by developing signatures for all naturally-occurring vegetation and surface conditions in the vicinity of the test area. These signatures were tested by means of comparison of computer signature printouts with NASA-supplied aerial photography.

Two large 512 by 512 pixel signature printouts were prepared which, taken together included the entire test area. Archaeological site signatures were tagged, lake and waterways were outlined. Subjective criteria based on location were applied to the tagged signatures. Unlikely locations were eliminated while the remaining possible sites were compared with known sites identified by field expeditions and NASA-supplied aerial photography. Of twelve known sites along the middle Khotol River, five were identified as sites on the computer printout and several more possible sites were located. However, seven known sites were not properly identified.

It was concluded that it is nearly feasible to use ERTS data and the techniques developed here to locate large archaeological sites. Several suggestions are offered to improve the feasibility of this approach.

17. Key Words (Selected by Author(s)) Archaeology Demography Interpretation techniques development		18. Distribution Statement		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified	21. No. of Pages 66	22. Price*

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PREFACE

1. <u>Objective of Project</u>: The objective of this project was to determine the
feasibility of detecting large Alaskan archaeological village sites
by satellite remote sensing techniques. The approach used was to
develop digital multispectral signatures of dominant surface
categories including vegetation types, exposed soils and rock,
hydrological patterns and known archaeological sites. ERTS scenes
were then printed out digitally in a map-like array with a letter
reflecting the most appropriate classification representing each
picel.

2. <u>Scope of Work</u>: During the first 6-months period, preliminary signatures
were developed and tested. It was determined that there was a need
to improve archaeological site identification by developing signa-
tures for all naturally-occurring vegetation and surface conditions
in the vicinity of the test area. These signatures were tested by
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expeditions and NASA-supplied aerial photography. Of twelve known

sites along the middle Khotol River, five were identified as
sites on the computer printout and several more possible sites
were located. However, seven known sites were not properly
identified.

3. <u>Conclusions</u>: It was concluded that it is nearly feasible to use ERTS
data and the techniques developed here to locate large archaeo-
logical sites. Several suggestions are offered to improve the
feasibility of this approach.

4. <u>Summary of Recommendations</u>:

1. Eliminate banding and striping in digital data. These effects
arising from poor intercalibration among the six ERTS MSS
photometers are particularly troublesome for signature
analysis where signatures are closely defined.

2. Use of scenes from other seasons. Shadow length could be
shortened by using solstice data thereby possibly providing
greater spectral resolution among signatures. Use of early spring
data might enhance identification of sites due to early vigor of
vegetation on archaeological sites.

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I. INTRODUCTION – ARCHAEOLOGICAL SITES IN ALASKA

A. The Potential Value of Remote Sensing to Archaeology in Alaska

The initial reaction to a suggestion of using remote sensing satellite data to locate archaeologically interesting village sites might naturally be one of skepticism. However, certain features of Alaskan village sites make remote sensing a promising means of establishing such locations.

1) The sites are relatively large. The site of a former village is usually considerably larger than the village itself was at any given period in its history. A village may remain in the same general location for centuries, but activity areas and the situation of individual dwellings within a village tend to vary over time. This variation creates a fairly large area disturbed from the natural state of the surrounding countryside.

2) The sites are generally inaccessible by road. Village sites may be found in the tundra, along abandoned or present beach lines, or in the interior, along rivers and streams. Because of the inaccessibility of many parts of the state, and the subsequently great expense of making ground surveys, no systematic search for abandoned village sites has yet been undertaken. Sites that have been located were stumbled across by accident, or found by an investigator looking in a likely spot.

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3) The area to be searched for potential sites is vast. Here the use of a remote sensing satellite is of special value. The cost of using aircraft for such a study is prohibitive—many times the amount for satellite data analysis.

4) The sites stand a good chance of being identified by remote sensing. Through time a village disturbs its environment. This disturbance ultimately leads to alteration of the relationships of various vegetable species growing within the perimeter of the site. In the past, multispectral scanning by satellite has proven useful in crop and crop disease identification. Therefore, this technique should also be capable of detecting variation in vegetation denoting the possibility of an abandoned village site.

5) The opportunity is timely. There is a general feeling in archaeology that more use should be made of remote sensing in site location, and that new techniques for doing this should be developed and tested. Supporting this opinion are remarks made by Elmer Harp, Jr. of the Department of Anthropology, Dartmouth College (1966).

"If archaeologists will exploit this kind of interpretation in depth, proceeding logically from the macro-levels of regional, natural topography toward the micro-levels of man's social and cultural activity, I am convinced that we

can learn to read minimal signs of past human activity on
the earth's surface. The most primitive and ancient traces
may have been obscured, perhaps entirely obliterated, by
physiographic processes, but short of drastic elimination,
any cultural activity with social magnitude is likely to
have altered the surficial environment and established a
chain of unnatural effects that will long endure. And as
long as these do persist, they will inevitably be reflected
in remote sensing imagery. Ultimately, I suggest, we may
penetrate to the stage of aboriginal, preliterate societies,
perhaps even to pre-historic levels of Palaeolithic culture.

These statements immediately suggest the need for
experimentation in technical approaches, for the essential
parameters of remote sensing in cultural analysis are
unknown. We must determine optimum scales for varying
conditions of environment and cultural stages, test the
relative utility of different film emulsions, and check
methods of remote sensing in the extra-visual bands of
the electromagnetic spectrum."

One well-known characteristic of Alaskan archaeological sites has
been the lush, tall grasses growing at these locations. It has
generally been accepted that several reasons exist for this change in
vegetational cover from the surrounding area: (1) disruption of the

original flora, (2) ground disturbances, (3) increased soil nutrients, and (4) economic patterns of the occupants. The relative strength of these factors are determined by (5) the period of occupation and (6) the technological development of the site occupants.

The general remote sensing technique is to determine the spectral characteristics of solar radiation reflected from a known site and then search for other geographical locations with the same spectral characteristics. The remote sensing study, therefore, requires the use of a known archaeological site. There are several obvious requirements for this known site: (1) It should be free from recent disturbance as possible, (2) It should be in an area where there is a likelihood of finding other sites nearby, (3) It should be large enough to give every possibility of being detected by remote sensing techniques, and (4) The period of occupation should have ended sufficiently long ago that the vegetational cover is representative of sites not mentioned in recorded history.

One site which appeared to fill these requirements was "Old Fish Camp" on the Khotol River near Kaltag examined by Frederika DeLaguna (1947) in 1935. The DeLaguna report supplied much needed information regarding this site, but lacked much additional information necessary for the present study. In particular, specific information regarding the reasons listed above for vegetational change were required. One very important item was the acquisition of radiocarbon samples to give some indication of the period of occupancy.

In order to obtain the needed additional information, a two-man field party visited "Old Fish Camp" between July 1 and July 20, 1972. The following sections treat individually the factors responsible for vegetational change determined by this field trip and concludes with a brief summary of what has been learned about "Old Fish Camp" to date.

B. Results of Field Trip to Known Archaeological Sites in Vicinity of Kaltag, Alaska

Ideally, the field work described here should be performed after the remote sensing data is obtained. However, it appeared that this postponement would cause at least a two-year delay in the final analysis of data. Furthermore, it was necessary to visit the site before analysis of remote sensing data because the exact location of "Old Fish Camp" was not known: the location was indicated on early United States Geologic Survey sketches.

Although DeLaguna (1947) excavated a house pit at "Old Fish Camp", additional archaeological information beyond that which she reported was sought. Radiocarbon samples from both high and low levels were sought to give some indication of the period of occupancy, faunal remains were sought to indicate the economic patterns of the occupants and stratigraphy would give an indication of ground disturbance. Cultural objects taken together with those reported by DeLaguna would indicate the technological development of the occupants.

Hence, it was determined to visit the site before the remote sensing data was taken, determine the accurate location, and obtain

the archaeological and biological evidence necessary to determine the parameters associated with the vegetation cover of the site at the same time. It was necessary then to obtain this data while disturbing the site as little as possible. Here, we will outline the technique used to accomplish this end.

Because some evidence exists to indicate the end of the occupation period, evidence indicating the beginning of site occupancy was sought. For this reason, we desired a shallow house pit indicating a longer period of abandonment than newer, deeper house pits. In addition, a house pit was sought which when excavated would alter the reflected solar radiation as little as possible. These requirements were met when a shallow house pit was found to the side of the main site which was located under several large overhanging willows. It has not been possible to detect this excavation on the aerial remote sensing data (photography).

As will be described later, it was necessary to collect soil and vegetational samples at intervals along a lateral and longitudinal transect of the site. It was soon discovered that the tall (over four feet) grass would not return to a vertical position once walked over. Hence, the transects were made with every effort to disturb the grass as little as possible. Where possible, the site was walked around to or from a transect station. Although a great deal of curiosity existed concerning various aspects of the site, these investigations were left to a later time when the vegetational cover could be disturbed without fear of destroying the reflected spectral characteristics unique to archaeological sites.

FACTORS RELATED TO THE PRESENT VEGETATIONAL COVER OF "OLD FISH CAMP"

1. Disruption of the Original Flora

There is extremely little direct archaeological evidence of the early alternation of the biotic community. It is assumed that disruption of the original flora consisted of removal or destruction of the trees in the area by activities related to the collection of wood for construction and other utilitarian purposes. In addition, there must have been considerable "tramping down" of the original flora. Indirect archaeological evidence was found that back dirt resulting from aboriginal excavations for the original dwellings as well as later refuse heaps were also agents in "smothering" the original flora. Fires may also have played a role in this initial disruption of the habitat.

Due to the nature of the sample, there is no well documented evidence of the first occupation of Old Fish Camp. Therefore, it is necessary to infer that the processes indicated by stratigraphic analysis of the upper levels, such as refuse heaps and house construction, occurred during earlier times as well. Direct archaeological evidence as to when and in what manner the site was originally disrupted is not available at this time.

2. Ground Disturbances

By far the greatest soil disturbances resulted from the numerous aboriginal house excavations. DeLaguna (1947) reported one house which was 18 x 17 feet with an entrance tunnel 15 feet long. This

house was of exceptional size and DeLaguna believed that it was a
Kashim, or men's house. Generally, the houses at "Old Fish Camp"
range in size between 9 x 10 and 13 x 15 feet. DeLaguna also noted
other disturbances which she described as being "from 2 or 3 feet
square, up to holes 3 x 8 feet. ... They were probably used for
storing salmon eggs or frozen meat."

The one house which was partially excavated in 1972 is illustrated
in Figure 1. It was very unlike those mapped by DeLaguna for it was
found to have been circular rather than rectangular. Because of the
permafrost present at the site, it was impossible to complete the
excavation of this house. However, all the structural material was
exposed, mapped and photographed in situ.

Here the construction details of the house which was partially
excavated are outlined. The house was approximately 3 meters in
diameter with what appeared to be a sleeping platform along the northern
wall (opposite the entrance). The platform consisted of undisturbed
alluvial sands and exhibited what appeared to be retaining posts along
its interior margin. The central living area was an aboriginally
excavated area with the less deeply unexcavated bench rising above it.
It possessed a centrally located hearth which was elevated above the
floor level. An entrance tunnel approximately 3.1 meters long
extended from the southeast corner and terminated in what was possibly
a cold trap.

DeLaguna originally mapped over forty house pits and noted that
many more were located in the willows and forested areas near the

B   Birch Bark
CB   Cotton, Wood Bark

N

0   1   2.5

2.5 CM = 1 M
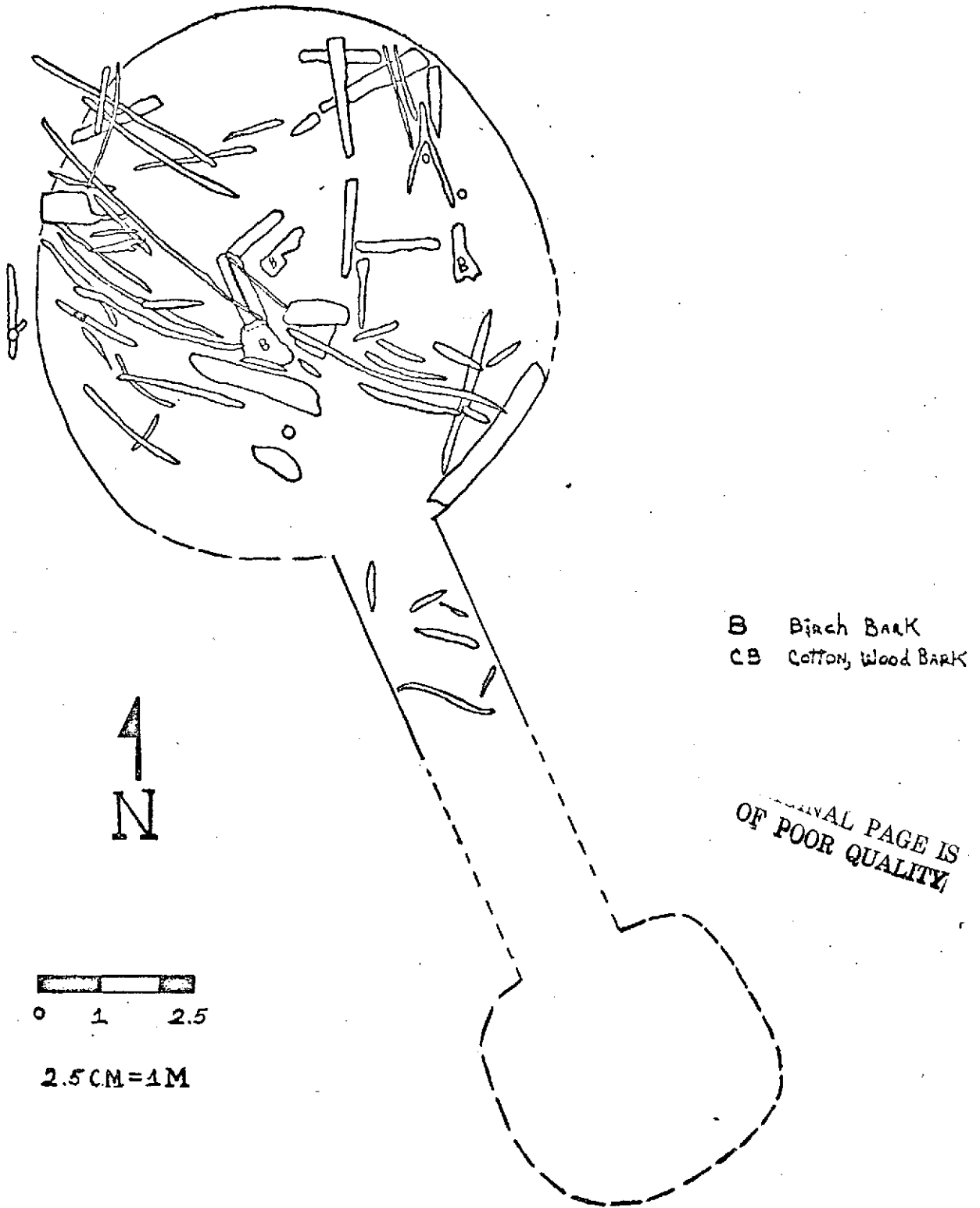
Figure 1.   Map of Old Fish Camp house partially excavated in 1972.

site. It is not unreasonable to estimate that possibly one hundred
house pits exist at the site, for the older house depressions are not
well defined and are obscured by vegetation cover as well as aboriginal
fill. The end result is therefore an extensive amount of ground
disturbance from house construction alone. The innumerable cache
pits as well as excavations for drying racks and the random digging
of dogs as well as men increased the ground disturbance beyond that
of house construction.

3. Increased Soil Nutrients

Unquestionably one of the most important agents responsible for
the marked vegetation change between the archaeological site and the
surrounding area is the increased nutrient value of the soil due to
the deposition of cultural refuse. Table 1 illustrates a tabulation
of the faunal remains recovered in 1972. The table illustrates that
no one species dominates the sample and that there is insufficient
representation of fragments and minimum number of individuals to
evaluate the importance of each species.

In order to realistically discuss the minimum number of
individuals in terms of meat represented, it would be necessary to
sample the site in sufficient detail in order that all activity areas
for butchering or bone processing could be located. Then an estimate
of the element transport differential and degree of fragmentation and
preservation could be made. The table does indicate, however, that
the inhabitants of the site were exploiting several different ecosystems

and had stratigically located themselves at an ecotone from which the individual ecosystems could be easily exploited.

Other factors also contribute to the change in the nutrient value. Although no coprolites were recovered, human as well as dog feces were most surely deposited. Birch bark for utilitarian purposes was also gathered in fairly large quantities and ash from fires is also incorporated in the midden debris.

TABLE 1

FAUNAL MATERIAL INVENTORY

	*M.N.I.	Total number of fragments	% of fragments
Large Fish	3	23	16.2
Medium Bird	2	22	15.5
Large Bird	1	1	.7
? Bear	1 ?	3 ?	2.1
Carnivore	1	1 skeleton	----
Rabbit	2	6	4.2
? Beaver	1 ?	3 ?	2.1
Muskrat	1	2	1.4
Small Mammal	---	18	12.7
Caribou	1	7	4.9
? Caribou	1 ?	6 ?	4.2
Large Mammal	---	16	11.3
Mussel (Anodonta)	1	2	1.4
Unidentified	---	33	23.2
Total	---	142 plus 1 skeleton	99.9

* Minimum number of individuals

In order to relate the nutrient value of the soil to the

vegetation, two sampling transects were made across the site (see Figure

2). Both soil and vegetation samples were taken at 30 meter intervals.

Unfortunately, the soil sample analysis is not yet compete. The

vegetation samples along the transects are listed in Table 2.

Conclusions relating soil nutrients and site vegetation will have to

be made at a later date. It can be readily noted that grasses and

herbacious plants dominate at the site proper and gradually give way

to willows and other broad leaf species.

4. Period of Occupation

Analysis of the radiocarbon samples from the site is not complete

and consequently a temporal sequence for the site has not been

established. DeLaguna (1947) reported a glass bead from the site

and therefore the site was not totally abandoned until sometime after

the contact period. Loyens (1966) quotes Jetté as mentioning this site

in passing in reference to a point on the Kaltag portage: "Loke-kayar-

rota-na-te-tti-retton-ten: Place where the people of Lokekayar have

or had their trail." Jetté adds, "when Lokekayar was permanently

inhabited, its residents used to have a trail straight from their

village, joining the Kaltag portage at this point." Loyens identifies

Lokekayar as "Old Fish Camp".

In Kaltag today there is at least one old man who relates

that there was a massacre at the village referred to here as "Old

Fish Camp" with few, if any, survivors. This possibility will have
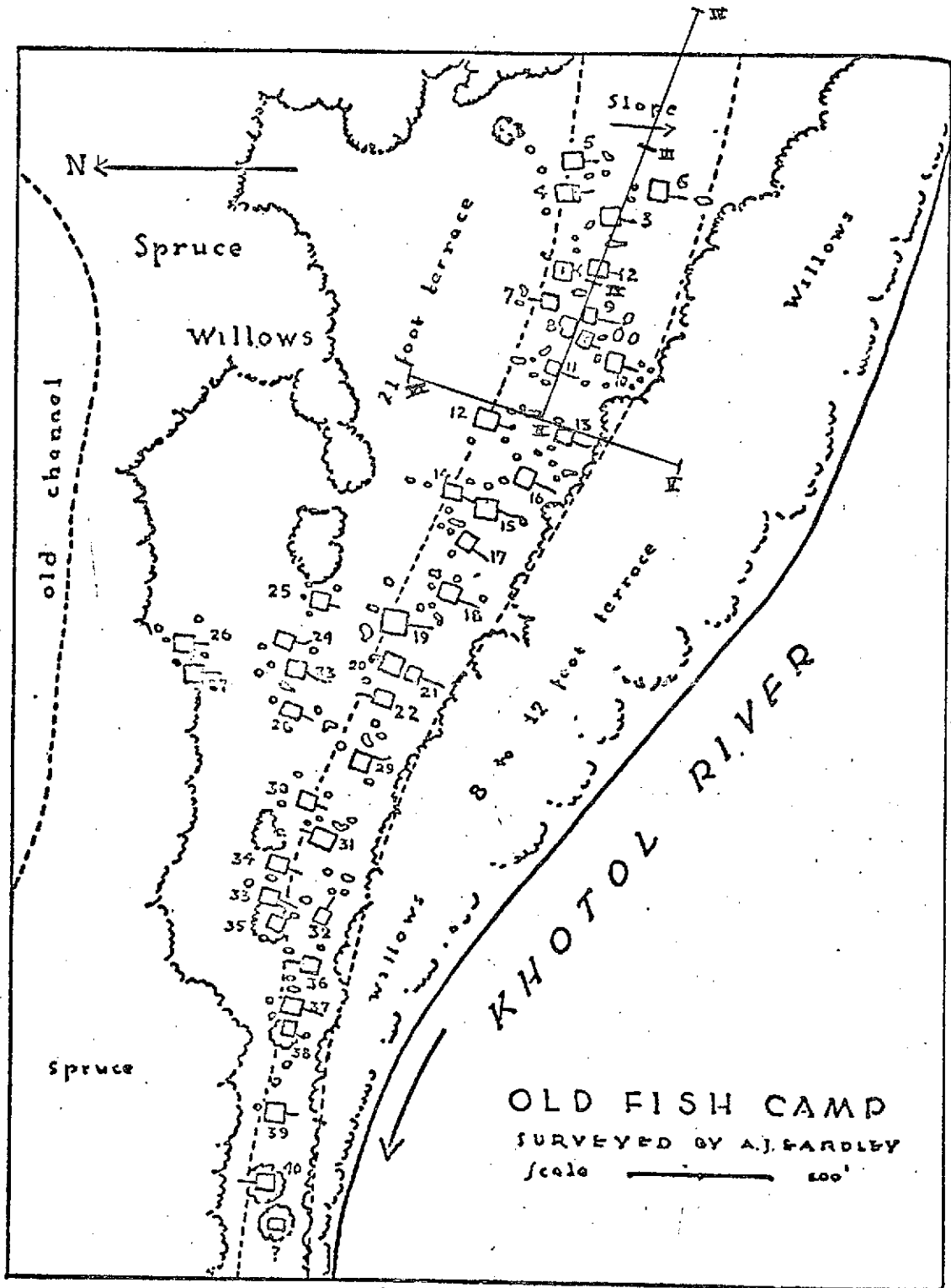
Figure 2. Map of Old Fish Camp (DeLaguna, 1947) showing 1972
          sampling transects.

TABLE 2

VEGETATION INVENTORY TRANSECTS

Longitudinal Transects

Species	Station	I	II	III	IV
Polygonum alaskanum		15%	15%	0%	0%
Mertinsia paniculata		5	15	5	1
Calamagrostis canadensis		68	60	69	39
Echinopanax horridum		2	0 ·	0	0
Rubus idaeus		2	2	3	5
Erysimum cheiranthoides		1	1	1	0
Galium boreale		2	2	1	2
Epilobium angustifolium		5	5	2	5
Salix		0	0	18	10
Thalictrum minus		0	0	1	0
Picea glauca		0	0	0	8
Betula		0	0	0	20
Equisetum arvense		0	0	0	10
Populus balsamifera		0	0	0	0

Lateral Transect

Species	Station	V	I	VI
Polygonum alaskanum		1	15	0
Mertinsia paniculata		5	5	10
Calamagrostis canadensis		2	68	55
Echinopanax horridum		0	2	0
Rubus idaeus		10	2	5
Erysimum cheiranthoides		0	1	2
Galium boreale		0	2	0
Epilobium angustifolium		1	5	2
Salix		40	0	10
Thalictrum minus		0	0	0
Picea glauca		3	0	10
Betula		0	0	5
Equisetum arvense		1	0	1
Populus balsamifera		37	0	0

to be investigated further. It does seem likely that permanent habitation ceased before 1850 but that the location may have been used as a camp for some time later.

A sample of ash from the central fire pit of the house was subjected to radiocarbon analysis. The age of the sample was found to be 490 $\pm$ 95 years. Hence, at this time we estimate that "Old Fish Camp" was occupied from at least some time before 1480 to around 1850 A.D.

5. Technological Development

Technological considerations are important when discussing the biomass harvest, ground disturbances, and subsistence patterns. This can be a limiting and regulating factor on the amount of food collected and thus on population size. The artifact inventory is listed in Table 3. A more thorough discussion of this inventory will be presented at a later date, although a few comments may be presented here. The good condition of the bone and wood artifacts argue for a fairly recent dating of the site while the typology, at least of the bone and slate points, may indicate an Eskimo influence if not an Eskimo habitation. So, too, does the pottery. However, the rolled birch bark, the birch bark baskets and the denticulate scraper are strong Athapaskan traits. This problem of Eskimo/Athapaskan identification is an important one which can only be solved by more excavation.

6. Economic Patterns of the Occupants

The name of the site, "Old Fish Camp", is somewhat misleading, for apparently it represents a much more permanent habitation site. The

TABLE 3

ARTIFACT INVENTORY

Bone Artifacts	No. of Specimens	Comments
A) Projectile Points	3	2 are fragments
B) Denticulate Scrapers	1	fragment
C) Bone Wedge	1	fragment
D) Adze Head	2	1 fragment
E) Knife Handle?	1	fragment
F) Worked Bone, "Scrap"	7	1 burned
G) Worked Antler, "Scrap"	2	
H) Unidentified	5	
Total	22	

Wood Artifacts	No. of Specimens	Comments
A) Worked Fragments	3	
B) Rolled Birch Bark	22	3 burned on one end
C) Complete Birch Bark Basket	1	
D) Birch Bark Basket Fragments	8	
E) Large Flat Pieces Birch Bark	3	
F) Structural Material (House)	86	
Total	145	

Ceramic Artifacts	No. of Specimens	Comments
A) Pot Shards	180	
Total	180	

Lithic Artifacts	No. of Specimens	Comments
A) Ground Slate Endblade	1	
B) Adze Blade?	1	fragment
C) Ground Slate Fragments	5	
D) Whet Stones	19	15 are fragments
E) Hammer Stone	1	
F) Obsidian Waste Flakes	7	
G) Quartz Waste Flake	1	
H) Geode	1	fragment
I) Fire Cracked Rock	228	
J) Stream Polished Pebbles	9	
Total	273	

TOTAL ARTIFACTS   598

numerous large semi-subterranean dwellings indicate a winter settlement of considerable size. The fact that fish remains constitute only 16.2% of the faunal remains also suggests that "Old Fish Camp" was anything but a fish camp. This is an important factor, for a seasonal occupation would limit the species represented in the deposits and dictate the type and form of ground disturbances.

II. DATA ACQUISITION

A. Oblique Hand-Held Aerial Photography

On July 8, 1972 an aerial reconnaissance of the "Old Fish Camp" area was made by light aircraft. This made possible a familiarization with the vicinity before detailed investigation on foot and by river boat. Many oblique color photographs were obtained by hand-held cameras. These photographs were found quite useful later when NASA-provided aerial photography was utilized to determine spectral signatures for vegetation: the oblique photography allowed an unambiguous identification of several vegetation types.

On August 5, 1974 the author had an opportunity to again overfly the study area in a light aircraft. This time oblique photos of likely locations of archaeological sites as determined from ERTS data were photographed.

B. Vertical-Incidence Multiband Photography

On July 25, 1972, just four days after the preliminary ground survey of the Kaltag-Nulato area had been completed, a NASA-provided aerial reconnaissance of the test areas was performed. The data

collected included single band black and white photography, color photography, color infrared photography and two-band thermal imagery. The aircraft used was the NASA/NP3A. All products are vertical viewing angle. The color and color IR photography were the principal products used in determining vegetation types for signature development.

C. Spacecraft Data

1. Multispectral Imagery

On July 25, 1972 scene 1002-21315 was obtained containing Nulato and Kaltag. This scene was received during November, 1972 and found to be of high quality in all four spectral bands. The fact that this scene was obtained only two days after the aircraft data was obtained made it especially valuable since no seasonal changes could have taken place during the interval and the multi-spectral aircraft data could be used to best advantage. Hence on November 27, 1972 a retrospective order was placed for the digital tapes for scene 1002-21315.

2. Multispectral Digital Data

Digital tapes for scene 1002-21315 arrived in mid December, 1972, and were converted into computer compatible tapes for analysis purposes. This task was completed by the end of that month.

III. DATA HANDLING AND ANALYSIS

A. First Signature Attempt

1. Digital Signatures

Upon receipt of the MSS digital tapes, the data for each band was printed out as a mosaic of digits for the quarter of the scene containing

the Nulato test site. After examination of the data for each band, it was
determined not to use band 4 at that time. This decision was formed due
to three factors:

(1) Position reference appeared to be different from the other
three bands.

(2) Intercalibration among the 6 photometers appeared to be poor
(with some scan lines reading intensity levels consistently
higher or lower than their neighbors).

(3) Atmospheric scattering appeared to cause the least image
definition in this band.

Hence, signature development was performed using only MSS bands 5, 6 and
7. In order to develop the first generation of signatures, the aircraft
imagery and ground truth data gathered at the test area were used to
determine which picels clearly represented various surface and vegetation
types. The intensity levels of bands 5, 6 and 7 for several picels
thought to represent the most significant surface features and vegetation
types were noted. Based on the range of values in each band, the following
preliminary signatures were identified:

TABLE 4

PRELIMINARY SIGNATURE IDENTIFICATION

Feature	Symbol	Band 5	Band 6	Band 7
Yukon river water (colored by glacial silt)	Y	18-30	omit	00-07
Stagnant lake (colored by vegetable matter)	L	00-10	omit	00-07

TABLE 4 (continued)

Feature	Symbol	Band 5	Band 6	Band 7
Khotol river water (combination of above)	S	11-17	omit	00-07
Grass	G	omit	32-45	18-40
Bare ground (mud)	B	omit	46-60	18-40
Willows and other broad leafed trees	W	7-11	18-25	11-14
Spruce trees	T	7-11	13-17	8-11
Possible archaeology site signatures on a scale of 1 through 8	A	9-11	26-31	15-17

The assignment of the numbers 1 - 8 for various archaeology site signatures reflected a rough estimate of probability of identification as a site. Roughly, the most probable is 8 and least probable, 1. Three known sites within the test area were used to determine the site signatures.

The picels of the 1/8th of the ERTS scene containing "Old Fish Camp" were subjected to a search for the above signatures. As a result, a computer printout was produced with the appropriate symbol occupying each identified picel. The printout magnifies the information contained on the ERTS 9 x 9" format to approximately 16 x 16' format and presents the MSS data with maximum resolution and grey scale range.

Although there was reasonable satisfaction with the results of the preliminary signature assignments and the printout of signatures, the

following problems and possibilities concerning the signatures developed thus far were noted:

Water signatures: The three signatures developed for water aided greatly in the interpretation of data. However, at least two additional signatures could be developed.

Vegetation signatures: Generally, these were satisfactory. However, there were several possibilities for improvement. It was felt that it should be possible to differentiate further between types of trees. Several bare ground signatures could probably be identified (rock, sand, mud). It was also felt likely that a signature for old burn areas - now containing shrubs and berries - could be found.

Archaeological Site Signatures: While reasonably satisfied with our preliminary archaeological site signatures, we felt that there was ample opportunity for improvement. The archaeological sites used as training areas are typical of such sites in much of Alaska; the former habitation area has grown over with a combination of willows and grass. Both of these species appear to be unusually healthy and lush. It is presumed that the quality of these species results from an increase of nutrients and other factors related to long term habitation.

In addition to identifying several known and potential archaeological sites, the preliminary archaeological site signature was printed out at several locations which are very likely not old habitation sites. We anticipated that

this might occur and discussed the possibility in our proposal. At that time, we suggested that we might use the presence of a waterway as a selection criterion. While this is very likely valid, we felt that a great deal of improvement could be made upon development of a second generation of signatures including a more sophisticated approach to habitation site signature identification in particular.

2. Signature Improvement

By means of a Zoom Transfer Scope, we compared the digital printout with the NASA-provided aerial photography of the test area. We sought to improve vegetation signatures as well as archaeological site signatures. Not all archaeological site signatures appeared at reasonable locations on the printout. In this work, we attempted to change the signature definitions to eliminate these identifications and retain known sites. In order to do this, a 1290 picel area was analyzed by direct methods.

3. Semi-automatic Methods of Signature Identification

In conjunction with U of A ERTS project No. 1, we worked with the development of a computer program which lists the number of picels with each reflectance level for each band within a defined portion of an ERTS scene. This information aided us in definition of signatures and other analytical approaches. Shown here as Table 5 is a histogram printout of this information for bands 4 through 7 for first, the small area analyzed above, and second, for a large 512 by 512 picel area containing that area. The histograms are semi-logarithmic.

TABLE 5

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   4 AND CHANNEL NUMBER   1. DATE=06/05/73 TIME=22.28.50
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF   1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL --------------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL	HISTOGRAM
13	2	0.15504	****
14	10	0.77519	*******************
15	169	13.10077	**
16	332	25.73642	**
17	225	17.44135	**
18	262	20.31037	***
19	251	19.45735	***
20	38	2.94574	*************************
43	1	0.07752	**
TOTAL	1290	100.00000	**

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   4 AT 22.28.51.

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   5 AND CHANNEL NUMBER   2. DATE=06/05/73 TIME=22.29.06
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF   1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL --------------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL	HISTOGRAM
7	11	0.85271	******************
8	101	7.82945	**
9	122	9.45736	***
10	222	17.20929	***
11	331	25.65891	**
12	320	24.80620	***
13	121	9.37984	***
14	56	4.34108	*****************************
15	6	0.46512	************
TOTAL	1290	100.00000	***

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   5 AT 22.29.08.

Table 5. Histogram of bands 4-7 for small and large areas showing Frequency Distribution of reflected intensity levels.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   6 AND CHANNEL NUMBER   3. DATE=06/05/73   TIME=22.29.23
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF   1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 101L, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

```
----------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL -------------------------- 1 - 3 --
                                                              1         5         1    5    0  0
                                                    1    5    0    0    0    0    0    0  0  0
 LEVEL    NUMBER   PERCENT                          0    0    0    0    0    0    0    0  0  0
  OR        OF       OF                        1    0    0    0    0    0    0    0    0  0  0
 CLASS    PICELS    TOTAL   .1......5.........0.......0....0....0....0....0....0....0..0..0.....
    6        1     0.07752 **         .         I    .    I    .    I    .    I    .    I   .
    7       10     0.77519 ***************          I    .    I    .    I    .    I    .    I   .
    8       29     2.24806 *********************         I    .    I    .    I    .    I    .    I   .
    9       20     1.55039 *****************         I    .    I    .    I    .    I    .    I   .
   10       13     1.00775 ****************         I    .    I    .    I    .    I    .    I   .
   11       13     1.00775 ****************         I    .    I    .    I    .    I    .    I   .
   12       12     0.93023 ****************         I    .    I    .    I    .    I    .    I   .
   13       11     0.85271 ***************         I    .    I    .    I    .    I    .    I   .
   14       34     2.63566 *********************         I    .    I    .    I    .    I    .    I   .
   15       13     1.00775 ****************         I    .    I    .    I    .    I    .    I   .
   16       20     1.55039 *****************         I    .    I    .    I    .    I    .    I   .
   17       60     4.65116 ***************************         I    .    I    .    I    .    I    .    I   .
   18       56     4.34108 **************************         I    .    I    .    I    .    I    .    I   .
   19       32     2.48062 ********************         I    .    I    .    I    .    I    .    I   .
   20       65     5.03876 ****************************         I    .    I    .    I    .    I    .    I   .
   21       71     5.50388 ******************************         I    .    I    .    I    .    I    .    I   .
   22       58     4.49612 ***************************         I    .    I    .    I    .    I    .    I   .
   23      107     8.29457 ****************************************         I    .    I    .    I    .    I    .    I   .
   24       93     7.20930 ***********************************  I    .    I    .    I    .    I    .    I   .
   25       67     5.19380 ****************************         I    .    I    .    I    .    I    .    I   .
   26       83     6.43411 ********************************         I    .    I    .    I    .    I    .    I   .
   27       33     2.55814 *******************         .    I    .    I    .    I    .    I    .    I   .
   28       39     3.02326 **********************         .    I    .    I    .    I    .    I    .    I   .
   29       31     2.40310 *******************         .    I    .    I    .    I    .    I    .    I   .
   30       32     2.48062 ********************         .    I    .    I    .    I    1.    I    .    I   .
   31       18     1.39535 ****************         .    I    .    I    .    I    .    I    .    I   .
   32       21     1.62791 *****************         .    I    .    I    .    I    .    I    .    I   .
   33        9     0.69767 *************I         .    I    .    I    .    I    .    I    .    I   .
   34       18     1.39535 ****************         .    I    .    I    .    I    .    I    .    I   .
   35       11     0.85271 ***************         .    I    .    I    .    I    .    I    .    I   .
   36       11     0.85271 ***************         .    I    .    I    .    I    .    I    .    I   .
   37       12     0.93023 ****************         .    I    .    I    .    I    .    I    .    I   .
   38       19     1.47287 ****************         .    I    .    I    .    I    .    I    .    I   .
   39       22     1.70543 *****************         .    I    .    I    .    I    .    I    .    I   .
   40       18     1.39535 ****************         .    I    .    I    .    I    .    I    .    I   .
   41       18     1.39535 ****************         .    I    .    I    .    I    .    I    .    I   .
   42        6     0.46512 ***********         I    .    I    .    I    .    I    .    I    .    I   .
   43       19     1.47287 ****************         .    I    .    I    .    I    .    I    .    I   .
   44       16     1.24031 **************         .    I    .    I    .    I    .    I    .    I   .
   45       21     1.62791 *****************         .    I    .    I    .    I    .    I    .    I   .
   46       14     1.08527 **************         .    I    .    I    .    I    .    I    .    I   .
   47       12     0.93023 ****************         .    I    .    I    .    I    .    I    .    I   .
   48        7     0.54264 ***********    I         .    I    .    I    .    I    .    I    .    I   .
   49        1     0.07752 **         .    I         .    I    .    I    .    I    .    I    .    I   .
   50        9     0.69767 *************         .    I    .    I    .    I    .    I    .    I   .
   51        2     0.15504 ****         .    I         .    I    .    I    .    I    .    I    .    I   .
   52        2     0.15504 ****         .         I    .    I    .    I    .    I    .    I    .    I   .
   53        1     0.07752 **         .         I    .    I    .    I    .    I    .    I    .    I   .
TOTAL     1290   100.00000 ****************************************************************         .    I    .    I    .    I    .    I   .
```

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   6 AT 22.29.27.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER 7 AND CHANNEL NUMBER 1. DATE=06/05/73 TIME=22.29.43
AREA OF SCENE COUNTED IS FROM LINE 130 TO 159 AND PICEL 258 TO 300, CONTAINING A TOTAL OF 1290 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=FROM 1038-21301 LINE 1011, PICEL 1 REEL 2
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ---------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL	Histogram
0	1	0.07752	**
1	31	2.40310	**********************
2	32	2.48062	**********************
3	10	0.77519	*****************
4	16	1.24031	********************
5	15	1.16279	******************
6	17	1.31783	********************
7	21	1.62791	**********************
8	48	3.72093	**************************
9	71	5.50388	*******************************
10	54	4.18605	***************************
11	99	7.67441	**
12	128	9.92248	**
13	147	11.39535	**
14	119	9.22480	***
15	85	6.58914	***
16	56	4.34108	*****************************
17	39	3.02326	**********************
18	33	2.55814	**********************
19	28	2.17054	********************
20	20	1.55039	*****************
21	23	1.78294	*******************
22	27	2.09302	*********************
23	25	1.93798	********************
24	25	1.93798	********************
25	33	2.55814	**********************
26	20	1.55039	******************
27	19	1.47287	*****************
28	15	1.16279	****************
29	12	0.93023	**************
30	15	1.16279	****************
31	4	0.31008	********
32	2	0.15504	****
TOTAL	1290	100.00000	

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER 7 AT 22.29.46.

EOF READ FROM INPUT TAPE IN PLACE OF ID RECORD. WILL REWIND AND CHECK FOR MORE CONTROL CARDS. PRESENT TIME=22.29.46.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   4 AND CHANNEL NUMBER   1.   DATE=06/05/73   TIME=22.37.43
AREA OF SCENE COUNTED IS FROM LINE   1 TO 512 AND PICEL   1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL -------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
6	9	0.00343
11	1	0.00038
12	93	0.03548
13	534	0.20370
14	4785	1.32533
15	46534	17.75131
16	85548	32.63397
17	41906	15.98587
18	38855	14.82201
19	19734	7.52792
20	3527	1.34544
21	322	0.12283
22	427	0.16289
23	280	0.10631
24	836	0.31891
25	1678	0.64011
26	8624	3.28979
27	7032	2.68250
28	649	0.24757
29	416	0.15869
30	168	0.06409
31	74	0.02823
32	33	0.01259
33	41	0.01564
34	2	0.00076
35	13	0.00496
36	1	0.00038
37	2	0.00076
43	1	0.00038
45	1	0.00038
47	1	0.00038
48	2	0.00076
59	1	0.00038
60	9	0.00343
70	1	0.00038
73	1	0.00038
74	1	0.00038
102	1	0.00038
104	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   4 AT 22.37.47.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR COU FILE NUMBER   5 AND CHANNEL NUMBER 2. DATE=06/05/73 TIME=22.39.47
AREA OF SCENE COUNTED IS FROM LINE   1 TO 512 AND PICEL   1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL ------------------------------ 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL	
2	2	0.00076	****
3	1	0.00038	**
5	44	0.01678	*********************
6	556	0.21210	**
7	5331	2.03362	**
8	29016	11.06873	**
9	38572	14.71405	***
10	50476	19.25537	**
11	43204	16.48102	**
12	41667	15.89470	***
13	21064	8.03528	***
14	8690	3.31497	**************************************
15	2316	0.88348	*********************************
16	752	0.28687	*****************************
17	406	0.15488	**************************
18	340	0.12970	*************************
19	460	0.17548	*************************
20	266	0.10147	**********************
21	494	0.18845	*************************
22	3256	1.24207	**
23	2859	1.09062	**************************************
24	9339	3.56255	**
25	2228	0.84991	*********************************
26	516	0.19684	**************************
27	91	0.03471	**************
28	41	0.01564	************
29	35	0.01335	***********
30	48	0.01831	************
31	25	0.09954	**********
32	12	0.00458	********
33	5	0.00191	******
34	4	0.00153	*****
35	5	0.00191	******
36	1	0.00038	**
37	1	0.00038	**
39	2	0.00076	****
50	1	0.00038	**
51	1	0.00038	**
52	1	0.00038	**
56	3	0.00114	*****
57	1	0.00038	**
59	2	0.00076	****
60	2	0.00076	****
61	1	0.00038	**
62	1	0.00038	**
66	1	0.00038	**
101	3	0.00114	*****
105	1	0.00038	**
122	1	0.00038	**
TOTAL	262144	100.00000	**

FREQUENCY DISTRIBUTION COMPLETED FOR COU FILE NUMBER   5 AT 22.39.51.

27

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   6 AND CHANNEL NUMBER   3.   DATE=06/05/73 TIME=22.41.45
AREA OF SCENE COUNTED IS FROM LINE   1 TO 512 AND PICEL   1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 REEL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

------------ HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL --------------------------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL
2	1	0.00038
3	6	0.00229
4	32	0.01221
5	112	0.04272
6	305	0.11635
7	578	0.22049
8	591	0.22545
9	595	0.22697
10	630	0.24033
11	741	0.28267
12	920	0.35095
13	1306	0.49820
14	2154	0.82169
15	4065	1.55067
16	5313	2.02675
17	16802	6.40945
18	15995	6.10161
19	11087	4.22935
20	15215	5.80406
21	13276	5.06439
22	10906	4.16031
23	19319	7.36961
24	16075	6.13213
25	13568	5.17573
26	25038	9.55124
27	9651	3.68154
28	22855	8.71949
29	12443	4.74663
30	10473	3.99513
31	9086	3.46603
32	4344	1.65710
33	3461	1.32027
34	2533	0.96626
35	2655	1.01280
36	1795	0.68474
37	1613	0.61531
38	1369	0.52223
39	1263	0.48180
40	896	0.34180
41	928	0.35400
42	248	0.09460
43	559	0.21324
44	355	0.13542
45	264	0.10071
46	205	0.07320
47	101	0.03853
48	130	0.04959
49	66	0.02518
50	83	0.03166
51	49	0.01369
52	35	0.01335
53	33	0.01259
54	10	0.00381
55	6	0.00229
57	1	0.00038
59	1	0.00038
82	1	0.00038
100	1	0.00038
135	1	0.00038
TOTAL	262144	100.00000

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   6 AT 22.41.50.

TABLE 5 (continued)

FREQUENCY DISTRIBUTION OF PICELS BY CLASS OR LEVEL FOR CDU FILE NUMBER   7 AND CHANNEL NUMBER   1. DATE=06/05/73   TIME=22.43.48
AREA OF SCENE COUNTED IS FROM LINE   1 TO 512 AND PICEL   1 TO 512, CONTAINING A TOTAL OF 262144 PICELS.
COMMENT FROM AREA SPECIFICATION CONTROL CARD=WHOLE SCENE FROM 1038-21301 RFFL 2, LINE 1011, PICEL 1
NOTE----LEVELS OR CLASSES WHICH HAVE A PICEL COUNT OF ZERO ARE NOT LISTED BELOW.

---------- HISTOGRAM OF NUMBER OF PICELS IN EACH CLASS OR LEVEL -------------------- 1 - 3 --

LEVEL OR CLASS	NUMBER OF PICELS	PERCENT OF TOTAL	
0	120	0.04578	**
1	512	0.19531	**
2	1200	0.45776	***
3	9294	3.54538	***
4	9239	3.52440	***
5	1951	0.74425	***
6	1653	0.63057	***
7	2117	0.80757	***
8	4961	1.89247	**
9	8847	3.37486	***
10	15557	5.93452	***
11	19845	7.57027	***
12	21425	8.17299	***
13	22642	8.63724	***
14	24670	9.41036	**
15	23215	8.85582	***
16	30107	11.48491	**
17	20866	7.95975	***
18	13520	5.15747	**
19	8915	3.40080	**
20	6104	2.32849	***
21	4438	1.69296	***
22	3258	1.24233	**
23	2069	0.78926	***
24	2042	0.77896	***
25	1205	0.45967	**
26	821	0.31319	***
27	503	0.19188	***
28	352	0.13428	**
29	283	0.10796	***********************************
30	169	0.06447	******************************
31	87	0.03319	**************************
32	73	0.02785	**********************
33	45	0.01717	******************
34	15	0.00572	************
35	14	0.00534	************
36	2	0.00076	****
37	1	0.00038	**
38	1	0.00038	**
39	1	0.00038	**
42	2	0.00076	****
46	1	0.00038	**
50	1	0.00038	**
56	1	0.00038	**
TOTAL	262144	100.00000	***

FREQUENCY DISTRIBUTION COMPLETED FOR CDU FILE NUMBER   7 AT 22.43.52.

EOF READ FROM INPUT TAPE IN PLACE OF ID RECORD. WILL REWIND AND CHECK FOR MORE CONTROL CARDS. PRESENT TIME=22.43.52.

EOF (/*) READ BY CARD READER. ERTSCOUN IS NOW DONE. PRESENT TIME=22.44.27.

Inspection of the histograms for band 4 (CDU file number 4 on the printout) shows that for the small area (1290 picels) there are only seven significant intensity levels while for the larger 512 by 512 (262, 144 picel) area, there are from three to four times as many intensity levels represented. More significantly, for the small area no signature domains appear obvious while for the larger area, there are two groupings of intensity levels which appear to represent dominant features. Further, note that the small histogram agrees with the upper portion of the large area histogram--even to the point that intensity level 16 appears most frequently. However, there is no correlation between the lower portion of these histograms. There is a large range of intensity levels represented on the large area histogram not indicated on the small area histogram. This indicates that the area was not homogeneous and that band 4 is more useful for signatures than one may have thought on the basis of the small area histogram. Examination of the large area histogram shows an unusual number of picels with intensity level 60. It remains to be seen whether this is significant or the result of statistics. Similarly, the histograms for bands 5, 6 and 7 were compared.

B. Second Signature Attempt

1. Approach to Problem

a. General

It was determined to develop a second generation of signatures for as many surface features and vegetation types as possible. The relationship

of archaeological site signatures to other vegetation signatures could be
accurately determined and hopefully the range of signatures used for
archaeological sites could be decreased while retaining those signatures
with the greatest likelihood of being archaeological sites.

b. Technique

A Zoom Transfer Scope was used to superimpose picel-by-picel intensity
level printouts with NASA-provided aerial photography of the test area.
The intensity levels in all bands were then transferred to a picel map
ruled into squares sufficiently large to write these numbers and a notation
of the vegetation type or types found in the area on the ground represented
by that picel.

Next, correlation scatter plots in band 5 vs. band 7 and band 6 vs.
band 7 were prepared. The scatter plots were approximately 4 x 4 ft. square
and ruled into squares so that for each intensity-level combination there
was room to note the number of picels with that combination and the vegeta-
tion types in that picel as recognized from aerial photography and ground
truth.

These scatter plots were then overlaid with tracing paper and the general
domains of each recognizably distinct signature delineated. The signatures
thus determined were then used to produce a new thematic computer printout
of the test area.

2. Results

a. Signature Development

Figure 3 shows the plots of generalized signature domains described
in the previous section. The meaning of the symbols, and intensity level
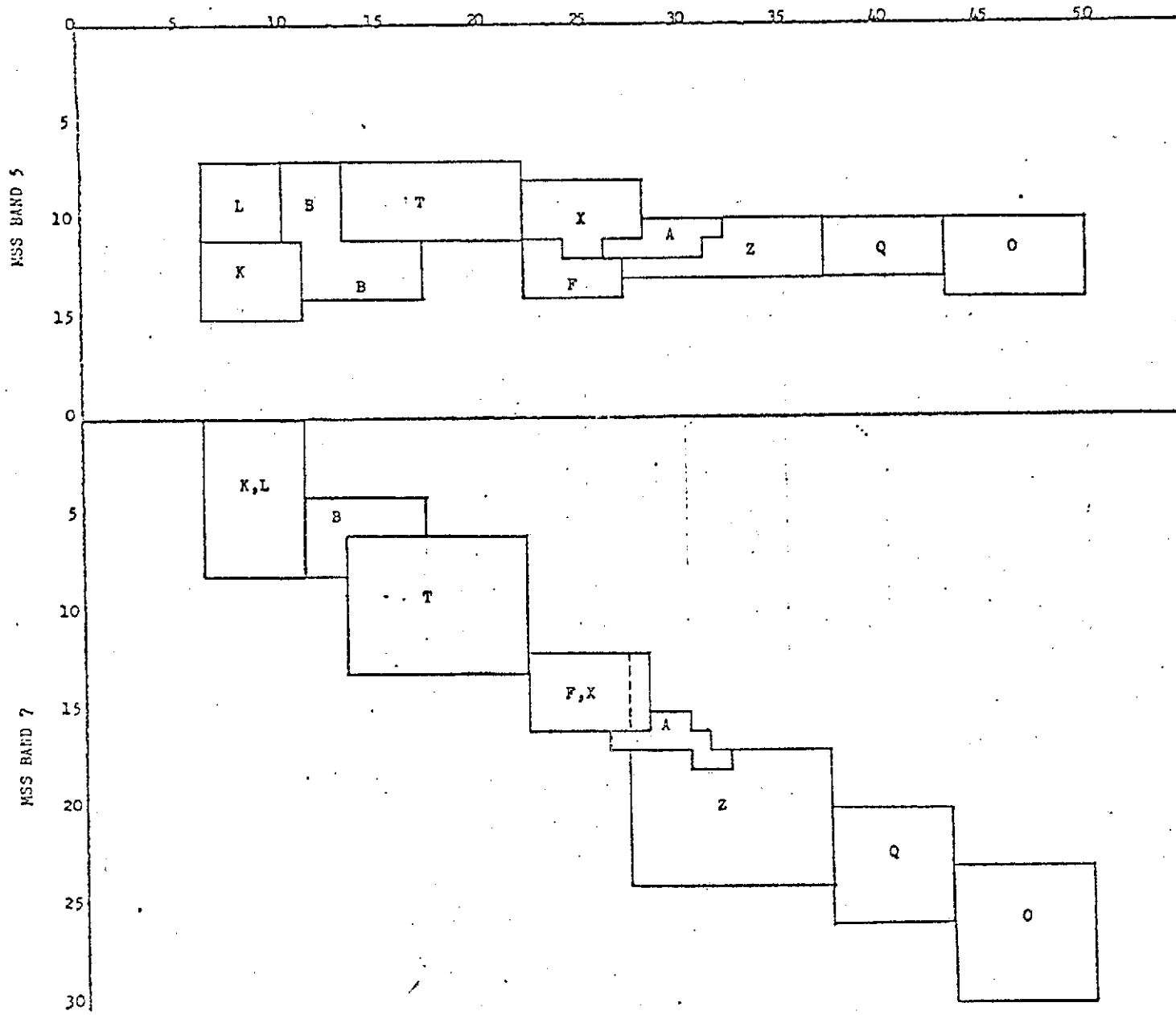
Figure 3. Two-dimensional projections of 3-dimensional signature domains. Considering digital reflectence levels in MSS bands 5, 6 and 7 as coordinant magnitudes, the idealized domains of each identifiable signature have been delineated. These two projections may be considered as a "top" and "side" view of a series of 3-dimensional domains. All picels with the combinations of intensity levels in each domain are identified on signature plots by the letter shown on that domain.

range for each signature are given in Table 6. As the table shows, most

of the signatures developed are for mixtures of vegetations and surface

features. This is because in this test area rarely are pure vegetation

types or surface features found in the area of a single picel. Indeed,

the archaeological sites themselves consist of a mixture of vegetation

types.

b. Signature Printout

Figures 4 and 5 show identical portions of ERTS scene 1002-21315

signature printouts. Figure 4 shows the printout performed on the basis

of the preliminary signatures, while Figure 5 is a printout based on the

new signatures. The new printout has been shaded according to vegetation

types. The following paragraphs contain a discussion of the newly-

developed signatures.

i. water course signatures

The major change here was to identify a signature for the bank of

the Khotol River and sloughs. Formerly the Khotol River signature was

given a rather broad range of definition with the result that picels

containing both the Khotol and a significant fraction of riverbank were

registered as "K". Here, we have narrowed down the range of definition

so that only picels located in the center of the Khotol River are

represented by "K" and picels located on its bank are represented by "B".

Note that generally the "Bank" signature is represented on one side of

the river or the other.

ii. vegetation signatures

As can be readily seen, the new printout contains signature symbols

for more vegetation type identifications than the old. Further, almost

```
SSSS      6557          WWWW              W
TLLSSSSSSSSSSSSSSSSSSSS WWWWW 75          W
WWWWW WSSSSLL TTTTTLSSSSS WW
SSSSSSSSI 75WW WWWWTWW SSSSWWW
LLLLLL WW WWW W8GWWTLTWWLSSTWW  5      W W W
 WWWWWWWWWW  WGGWWW WTWWSSSW             W
WWWWWWWWW   WW GWW7G8 L  SSW
WWWWWWWWW8GGGG  GGWW6G TTTTSS 8WWW     WW W5
WWWWWG8    GGG WGGWW GG TT SSSWW     W
W5GG   GGGG GGGG GGWWWGGWWTTTSST      W
GGGGGGGGGGGGGGG8G7WWW8 W8 T SSSWWWW
GGGGGGG8GGGGGGGGGGWWWW7 57TTTTSSW
GGGGGGGGGGGGGGGGG WWWW  W8W T SS WW      5W
8GGGGGGGGGGGGGGGG8WW W86WG8TTWSSTWW     WTT
G8 GGGGGRR98GGGGG  WWWW5 7 8    SSSW    WTT
GGG GG5T GGRRGGG W   WWW5GGT TSSSW     WTT W
8GGGGGGIL26WG88GGGWWB WWW GWWWTSSSWW   WLTWW
BBBBBGG T 8 BBBG WWS WWW 8W WTSS W    WLT
GBBBBGGG 8GGGBGGW   B  W WW5 TSS        85W
BBBBBBGGGGGGGGGG8G3W 63 W WL 7 TWSSW  WWW 7WW
 GGBBGGGGGGGG8GWW88 WTW 8WT    SS   5W  W
G GBGGGGGBGG BGGW G6W W GW WTWSS   WWWW
TW!GBGGGBBG 8BGGW8G8W W    TT SS    W
TTTT GBBBBBG BB W G WWWWWTTWWSSS  ·       8
6      WGGGG  GBBW8G  WW WWW SSSW   W  67 W
WGGG6W TTWW6 GGG T WW W688WSSST WWTLT WWWWW
GGGGGG   TT WWW6LTWWSSSSSSSSSL WWWLLW  W  W
8GGGGGG TLTTT TTTSSSSSLLTTWWW WWWW
W5GGGGG TT TTTSSSLT  WW   W8 WW     WWW
 GG   B GWWWWTTSSSTTWWT  WWWW G
```

Figure 4. Printout of preliminary vegetation signatures in the vicinity of Old Fish Camp. Signatures were derived for slough (of the Yukon River) (S), willows (W), large trees (T), grass (G), bare ground (B), and probability of archaeological site (1-8). The archaeological site probability is greatest for an "8" signature. Information is from a portion of ERTS scene 1002-21315.

Figure 5. Printout of second generation signatures described in
text. Here archaeological site probability is inversely
proportional to magnitude of numbers 1-7. Groupings of
similar signatures have been indicated by shading.
Improvement over signature classifications illustrated
in Figure 4 include recognition of combinations of vege-
tation types and identification of greater number of
distinct signatures. The quantity of pixels with possible
archaeological site identification has been drastically
reduced.

TABLE 6

SYMBOL	CLASSIFICATION
1-7	Signature characteristic of former (archaeological) habitation sites, probability inversely proportional to number
K	Khotol Slough (slough of Yukon with additional drainage)
L	Lake
Y	Yukon River
P	Stands of predominately large spruce
T	Large trees (combinations of spruce, birch and aspen)
B	Bank of slough (average of slough and vegetation)
F	Vegetation characteristic of old burn (scrub trees, grass, berries)
X	Combination of mainly small black spruce and some willow and grass
Z	Combination of willows, grass and bare ground
Q	Combination of water puddles, wet bare ground and grass
O	Largely bare grass
+	Submerged sand bar
*	Sand bar
.	Average of general vegetation, sandy bare ground and water

none of these new signatures are for a pure vegetative type. Here we will
discuss each of these new signatures.

P   Stands of predominately large spruce trees. Picels printed out
    with a "P" are shaded darkest of Figure 3. These are generally
    trees of sufficient size to be considered of potential commercial
    value. Comparison with NASA-provided aerial photography shows
    this signature to be reasonably accurate (see discussion of "T").

T   Large trees (combinations of spruce, birch and aspen). Although
    not shown in Figure 3, band 4 was found to have utility in differ-
    entiating between T and P signatures. This differentiation is
    reasonably good with its greatest deficiency being that band 4
    is subject to relatively poor intercalibration among the MSS
    detectors. As a result, there appears to be some error introduced
    into the T/P decision.

X   Combination of mainly spruce with some willow and grass. Note
    that this signature is differentiated from the "F" signature only
    through band 5. The vegetation type represented here is much lower
    in height than that represented by "T" or "P". The spruce combination
    is often black spruce which is generally smaller than white spruce.

F   Vegetation characteristic of old burn. The area to the right of the
    Khotol River was the site of a forest fire in 1958. As character-
    istic of many fires in interior Alaska, there were many pockets of
    unburned trees within the area of the fire. The area that burned
    is now moderately lush with scrub spruce, and many low-lying berry
    plants and grasses. Although the vegetation in "X" and "F" picels

are moderately distinct, as noted above, a spectral distinction
can only be made in band 5. With this close distinction it might
be expected that many picels would be mislabeled, and indeed one
can find "F" signatures on the left hand side of the Khotol River
where it is unlikely there has been a fire in recent times. However,
it is still possible that "F" vegetation type can be found on this
side of the river. Moreover, it is interesting to note that there
are relatively large areas of contiguous "X" picels and also
relatively large areas of contiguous "F" picels. This result
indicates that the distinction between these two signatures is
reasonably accurate and significant.

A Signatures characteristic of former habitation sites. This group
of signatures (numbers 1 through 7 on the printout) is discussed
in detail under the next subsection heading. Here we wish to point
out that the signatures for known sites lie within a moderately
close range (see Figure 3). The vegetation on these sites
generally consists of unusually vigorous grasses and willow. The
unusually healthy state of these plants results from fertilization,
soil mixing and aeration resulting from former habitation activities.

Z Combination of willows, grass and bare ground. This vegetation type
is characteristic of much low-lying wet ground and is often
interspersed with patches of mud. The mud patches are probably
maintained in part by the grazing activities of moose. The
tendency toward mud patches is one feature which generally helps
distinguish "Z" picels from "A" picels. However, the distinction

is not complete as evidenced by several patches of 6's, a lower probability archaeological site signature. These patches of 6's should very likely be Z's.

Q Combination of water puddles, wet bare ground (mud) and grass. Picels with this signature have been shaded slightly darker than the picels with "O" signatures. Note that the Q's often align themselves in rather long strings. There are several former river channels in this area which now consist of lineated low-lying areas.

O Largely grass. There is no clear line of distinction between this signature and "Q". However the choice made appears to have differentiated between two surface conditions in that Q's and O's are not randomly distributed with respect to each other but rather appear in separate groups. Comparison with aerial photography generally bears out the distinction made.

. Average of general vegetation and sandy bare ground. This signature was found to represent picels located along riverbanks and other areas where moderate expanses of dry sandy soil with perhaps some vegetation occurred.

    iii. archaeological site signatures

1-4, signatures of known archaeological sites. The locations of these signatures determine the boundaries of the signature volume labeled "A" in Figure 3. Any picel represented by these numbers has the same combination of reflectance levels as a known archaeological site. There is the possibility however, that the banding effects

mentioned earlier are at least partly responsible for the identification
of some picels as 1, 2, 3 or 4 simply because there are variations of
the average intensity level on the order of one unit among the six
detectors monitoring each MSS band.

5-7, signatures approximate to those of known archaeological sites.
Considering the intensity levels in bands 5, 6 and 7 to define an
ordinary orthogonal 3-space. Signatures 1 through 4 define the outline
of a 3-dimensional solid. This solid has been subdivided into three
smaller volumes labeled 5, 6 and 7. The ordering sequence being
determined by a subjective judgment was based on the relative proximity
to signatures of known sites.

Of the 262,144 picels examined in this portion of ERTS scene
1038-21301, a total of 7,890 or just under 3% were classified as 1 through
3. The most frequent classification was "6" with 4,243 or 1.6% of all
picels. It is not believed that these are unreasonably high percentages.
Further interpretation of the probability of a picel with a classification
of 1 through 7 actually being an archaeological site will depend on its
position relative to other classified picels. For instance, the life
style of peoples in this area was directly linked to fishing and water
transportation. Hence identified picels at any distance from water
courses can be ignored. This additional decision-making process will
greatly reduce the number of possible locations of archaeological
sites.

C.   Detailed Analysis of Second Generation Signatures

Since our data analysis plan calls for printing our digital
signatures for a portion of an ERTS scene, it is very important that

the signatures developed be applicable without modification to a wide geographical area within each scene, if not throughout the whole scene. In terms of archaeological village sites which have a very narrowly-defined signature range this could be a significant problem.

Therefore, before using the digital printout as an inventory of possible archaeological village sites, the printout should be tested at selected locations to determine whether or not signatures of well-known features are being correctly identified. One could then infer that the site signatures are remaining correct also.

This was done and the results were found satisfactory. One example of this test is illustrated in Figure 6. This figure consists of a two-frame mosaic of aerial photographs and the corresponding portion of our digital signature printout. The signature symbols were defined in Table 6.

The area illustrated here contains the present-day village of Kaltag, located on the west bank of the Yukon River just below the top of the photograph. The village and its airstrip have been outlined by rectangles on the printout. It is interesting to note that because there were no present-day habitation sites in the signature training area, no signatures were developed for that kind of feature. Consequently, the Kaltag area is largely blank on the printout. Three signatures can be found within the village area: the dot (˙) signature standing for an average of general vegetation, sandy bare ground and water (in that order), the "F" signature standing for vegetation characteristic of a burned area (approx. 15 years before), and a "7" signature representing vegetation characteristic of an archaeological site.

Aerial photograph (top) and digital printout of ERTS signatures (bottom) of small 1x2 1/2 mile area including Kaltag, Alaska. Aerial photographs obtained from 5,000 feet. ERTS data obtained from altitude of 500 miles. Digital tape of ERTS scene 1038-21301, covering area 110 miles square, was utilized for printout. Signatures displayed here were obtained through analysis of training area fifteen miles distant.

The occurrence of the dot within the village should be expected; there are large expanses of bare ground (paths, roads, dog tie-down areas, wood-chopping areas, etc.) and other areas of grass including some sod roofs. The two "F" picels within the village and the large area of "F" picels to the west probably result from a fire adjacent to the village within the historic past. The archaeological signature within and those adjacent to the village very likely do not indicate old habitation sites but rather vegetation characteristic of modification of soil conditions due to nearby human occupation (fertilization, etc.). That is, the conditions responsible for development of archaeological site signatures probably apply at least in part in areas adjacent to present day villages.

Across the Yukon River from Kaltag, a slough of the Yukon can be seen which meanders first east, then south, then east with a small gooseneck to the north and finally north. The presence of Yukon River water in the slough is demonstated by the occasional "Y" signature found along its course. One should note that in order for a picel to be labeled with a "Y" signature, it must be fortuitously located squarely within the banks of the slough. Otherwise spectral averaging will occur with the result that the reflectance levels measured correspond to a different signature, or more likely to no defined signature at all. This result can be seen between the "Y"'s. The "B" signature which was developed to define the bank of a slough with different spectral characteristics than the Yukon River, was still close enough to define the bank of the slough in some places. More importantly,

however, the "B" signature traced this slough of Yukon River water after

it became so narrow that spectral averaging took place in all picels

containing it. This is an added utility of that signature not

anticipated.

The banks of slough such as this one are usually elevated due to

deposition of material during flooding. Very often this elevated

area contains large spruce and birch trees. This phenomena is parti-

cularly well illustrated here on the east side of the south-going portion

of the slough. Note the band of "T" and "P" signatures paralleling this

portion of the slough.

Blank areas generally contain vegetation not found in the training

area. At this point signatures for these unidentified areas could be

determined. Of particular note is the blank area just north (above) of

the gooseneck of the slough. Examination of the aerial photograph

shows this area to contain vegetation considerably different in appear-

ance from any other in the photograph with the possible exception of

that found in some portions of the dried-up ox-bow lakes between the

Yukon River and the south-going part of the slough. This vegetation

is probably a stand of large willows.

Along the east bank of the Yukon River can be found a number of

picels represented by archaeological village site signatures. One

should recall that a "1" is the most probable and a "7" the least

probable site signature. Three areas of relatively high average site

probability have been delineated on the printout. When Schwatka

surveyed the Yukon River in 1887, he indicated the village of "Khaltag"

at approximately this location. This identification has not been field-checked.

Thus it was concluded that the signatures developed are valid over a wide geographical area. The distance between the area used here to test signature validity and the training area where the signatures were developed is approximately fifteen miles.

IV. RESULTS: COMPARISON OF AERIAL PHOTOGRAPHY WITH SIGNATURE PRINTOUT

Following verification of signature identification the locations of the three most probable archaeological site signatures for an area approximately fifteen by thirty miles were transferred from the printout to transparent overlays on USGS 1:63,360 maps. The major features of the USGS maps were added to these overlays. These overlays, reduced to page size, are shown here as Figure 7. For convenience the potential archaeological sites have been given an identifying number.

Each numbered possible site was located on the NASA-provided color and color infrared photography and examined in terms of the likelihood that it was an archaeological site. A great many of the potential sites were eliminated from consideration by this process. Usually, one of two major factors was involved: either the potential site was located far from a waterway, or it was very low-lying. The first selection factor is justified on the basis that the aboriginal life style called for village location near a watercourse sufficiently large for navigation by canoe. The second selection factor is justified on
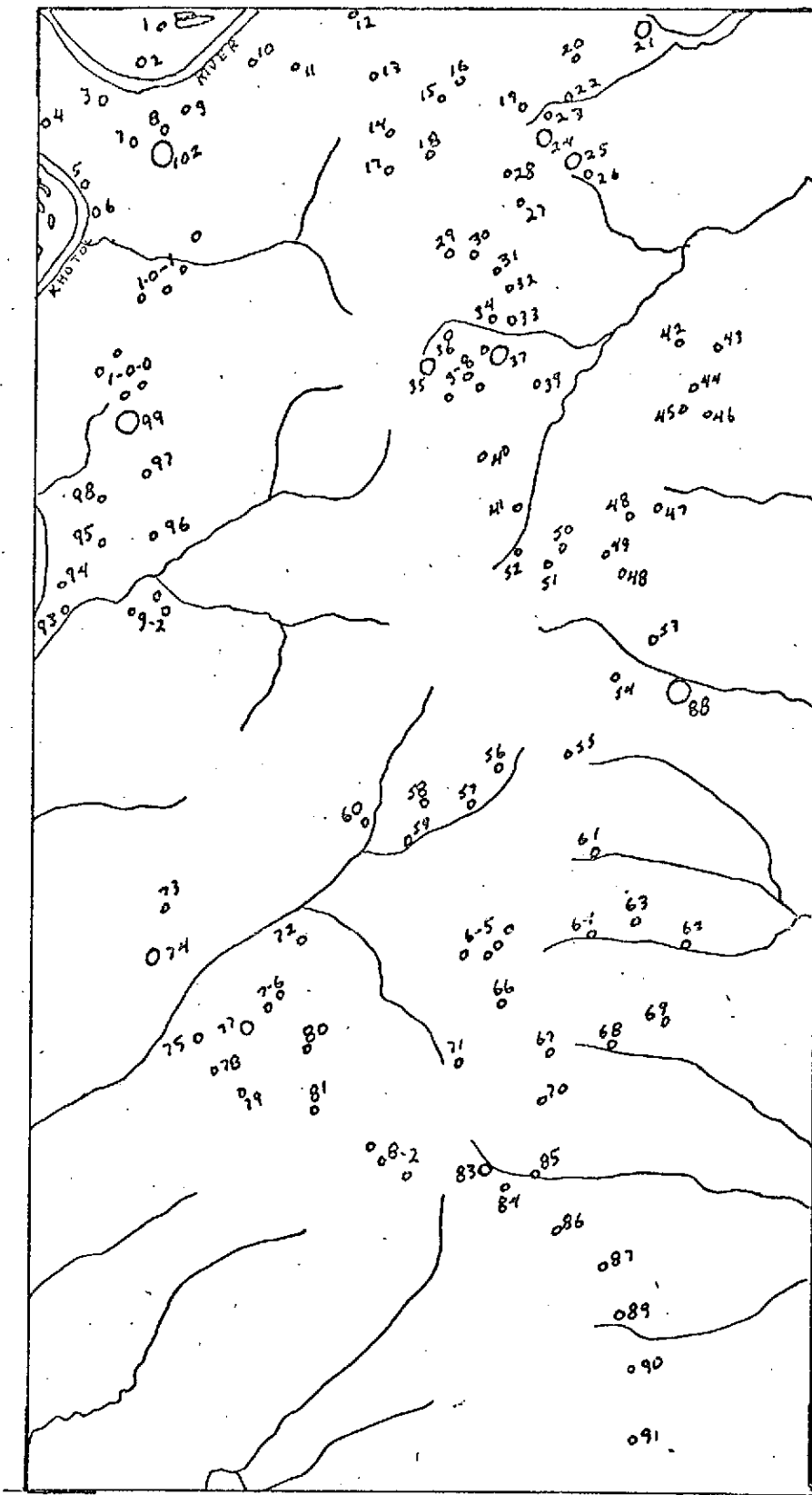
NULATO (A-5)

Figure 7a. Xerox reduction of 1:63,360 map overlay showing

locations of archaeological site signatures in the
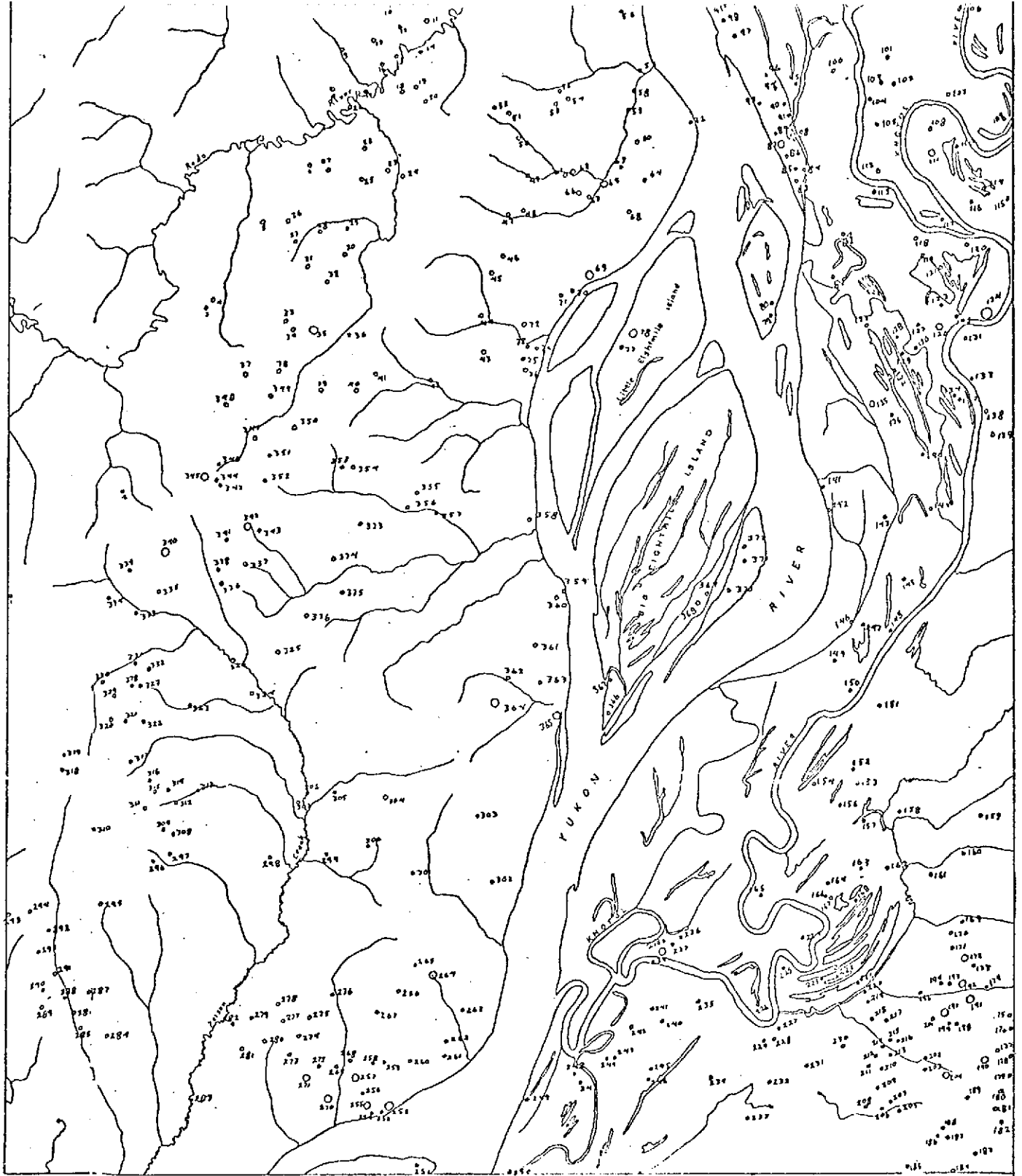
Kaltag, Alaska area.

Figure 7b. Xerox reduction of 1:63,360 map overlay showing locations of

archaeological site signatures in the Kaltag, Alaska area.
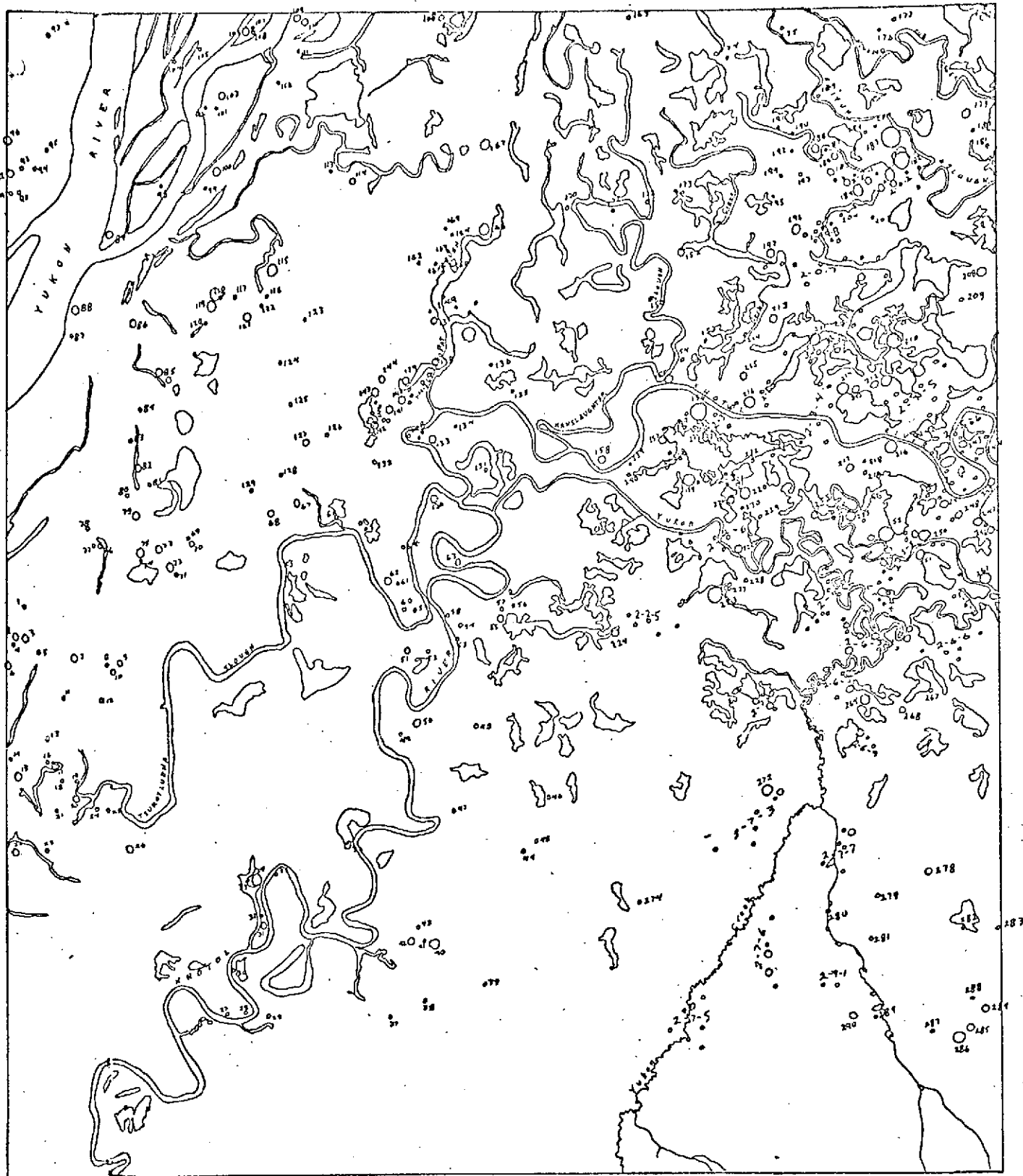
Figure 7c. Xerox reduction of 1:63,360 map overlay showing archaeological
site signature locations near Kaltag, Alaska.
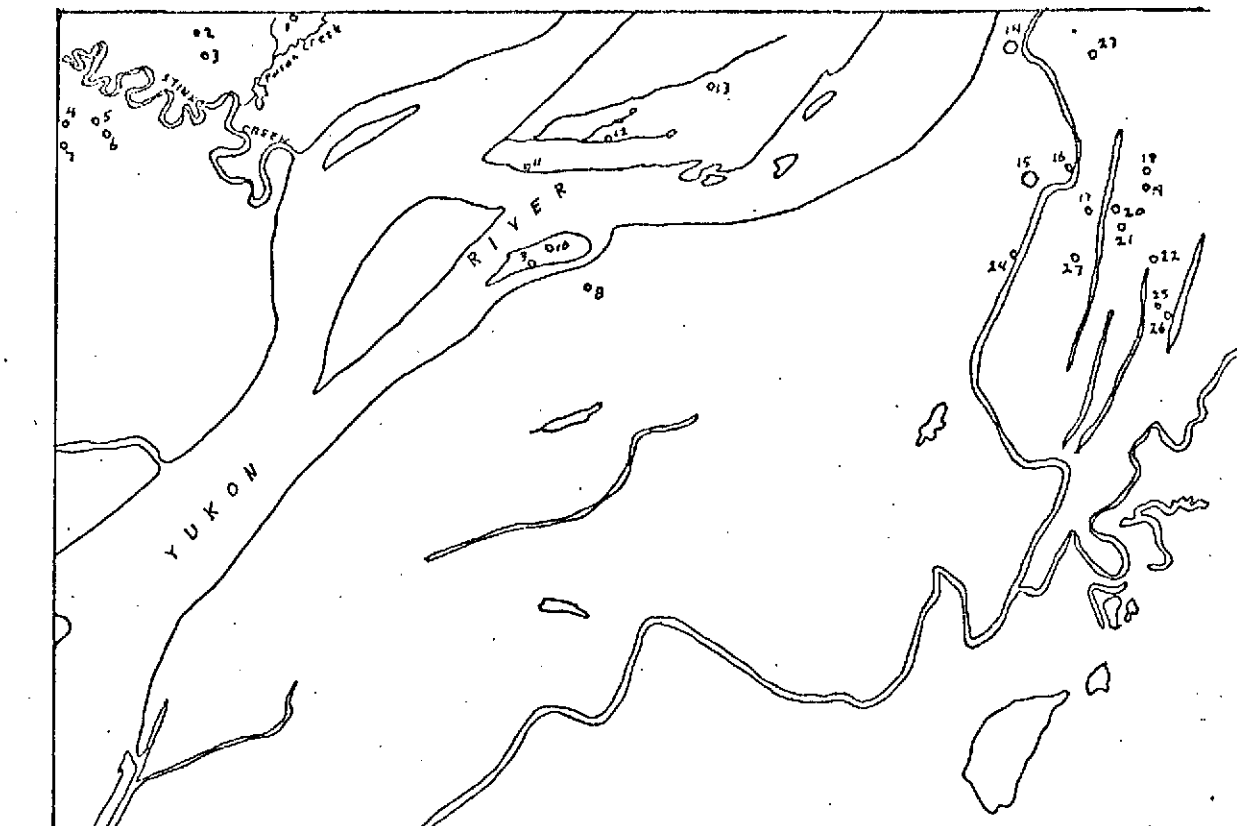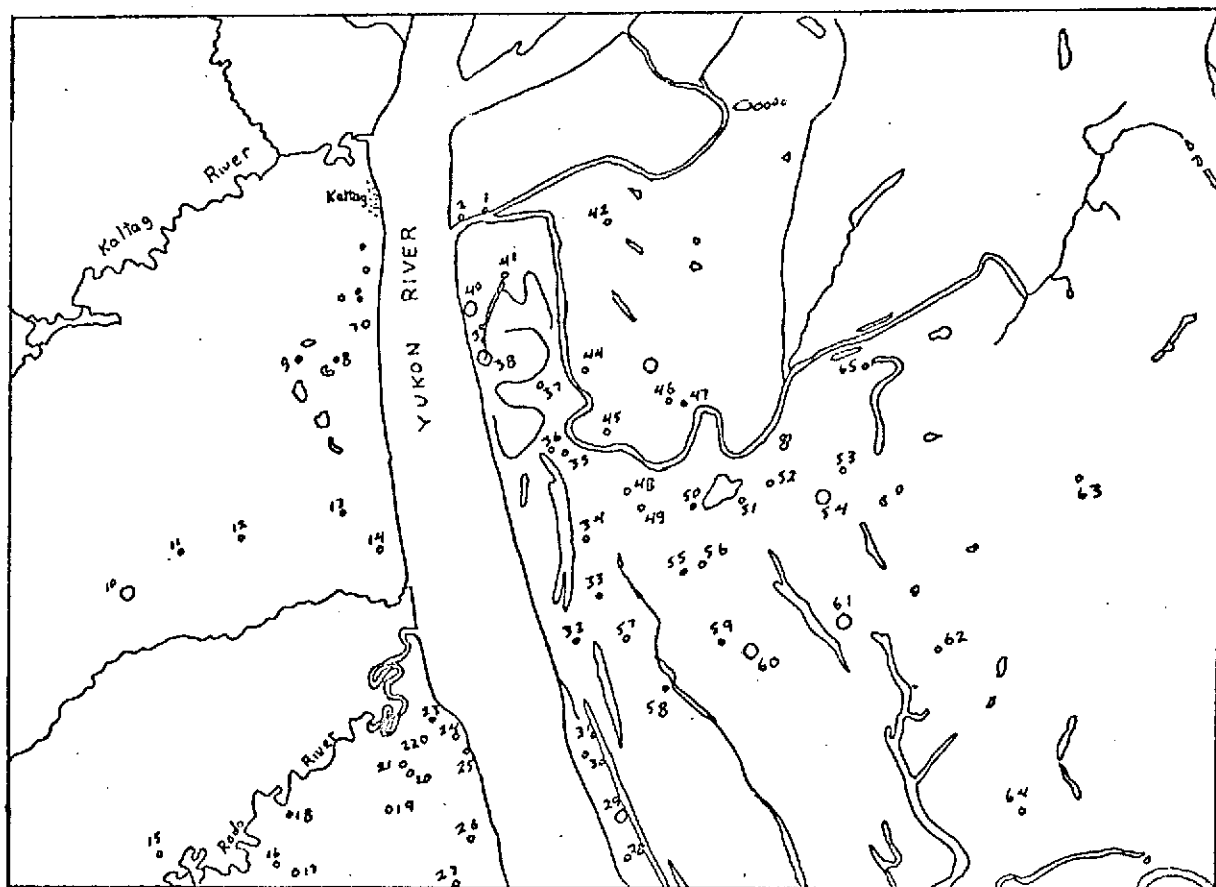
Figure 7d. Xerox reduction of 1:63,360 map overlays showing the locations

of archaeological site signatures in the Kaltag, Alaska area.
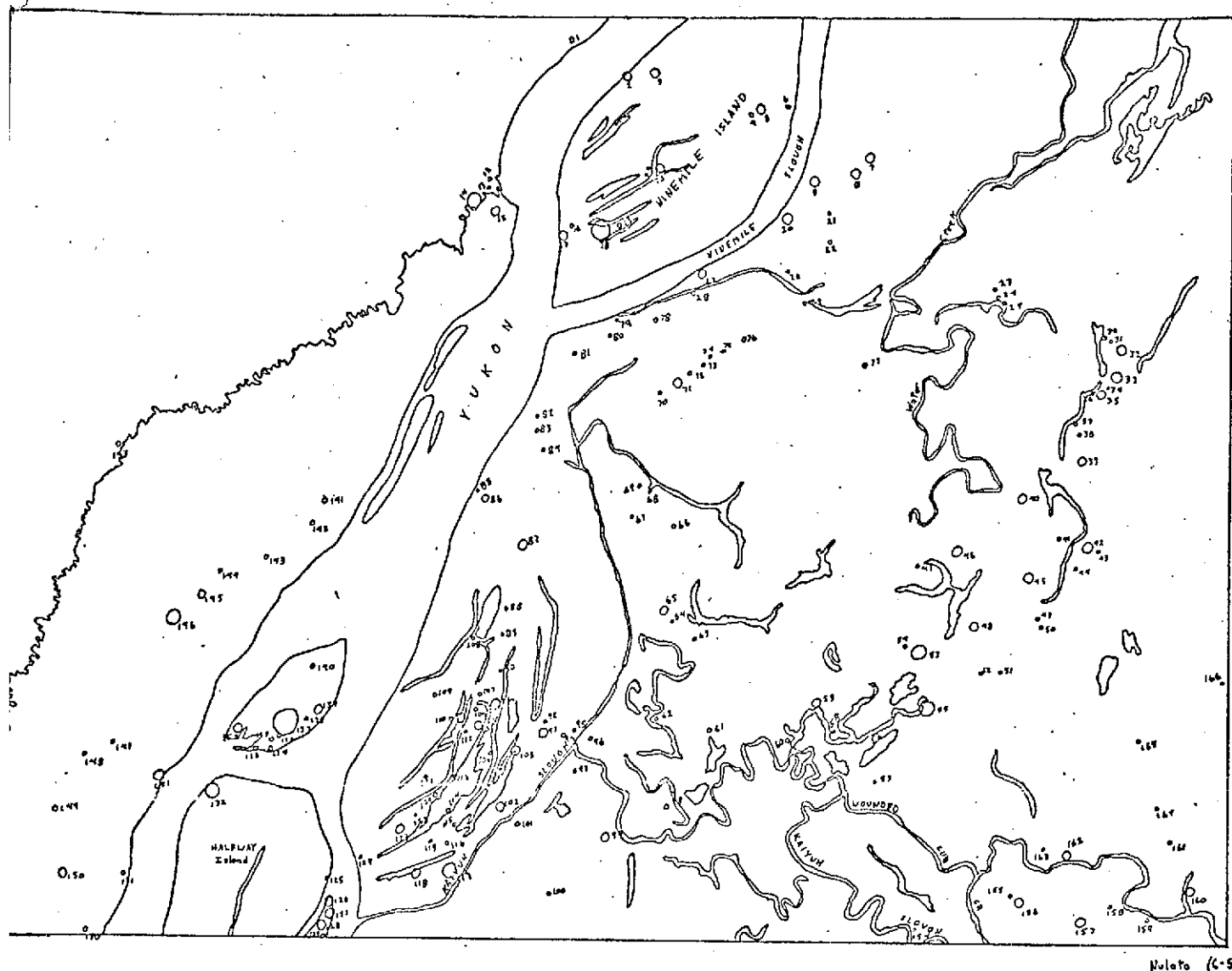
Figure 7e. Xerox reduction of 1:63,360 map overlay showing the locations

of archaeological site signatures near Kaltag, Alaska.
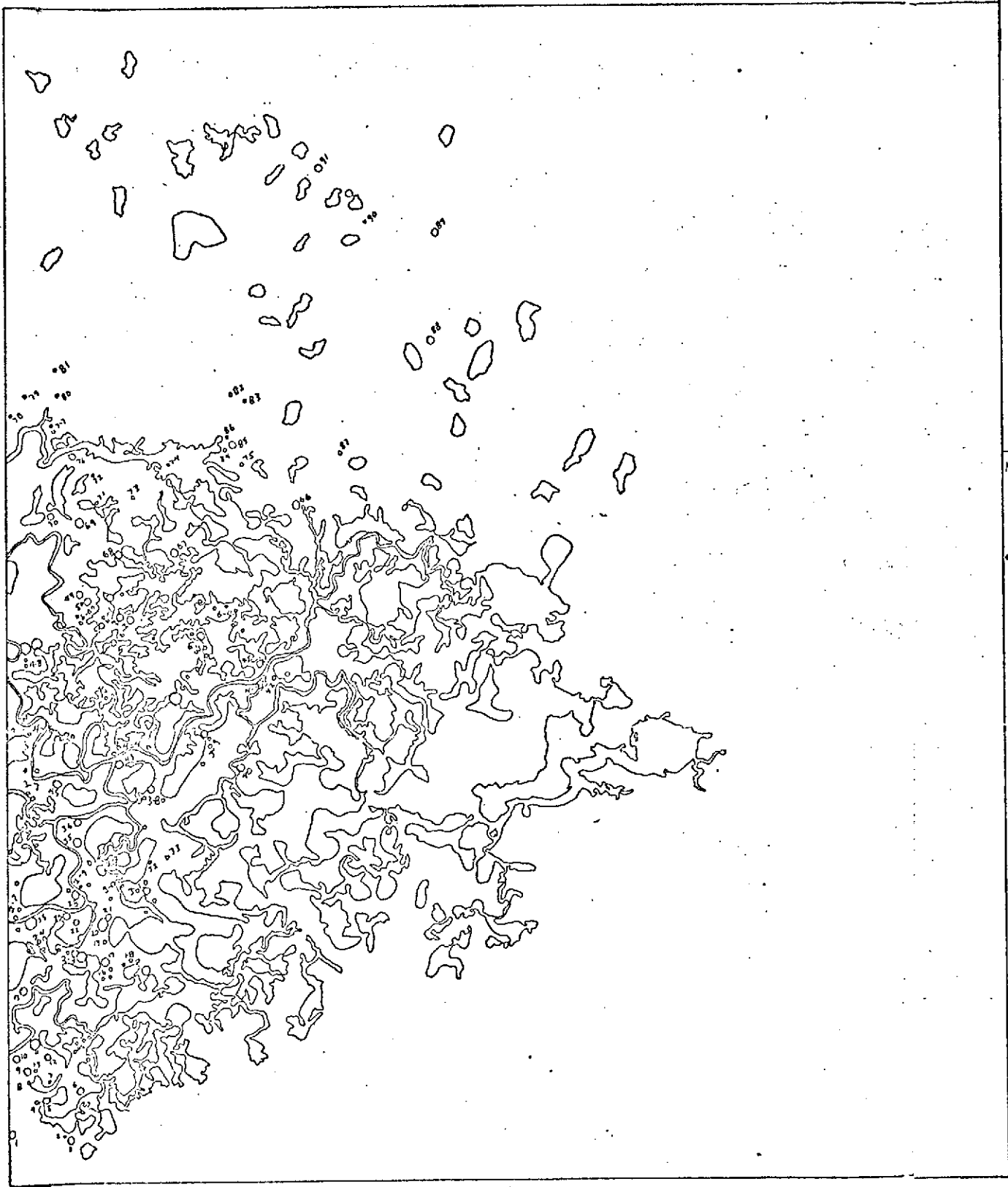
Figure 7f. Xerox reduction of 1:63,360 map overlay showing the location of
archaeological site signatures in the Kaltag, Alaska area.

the basis that sites are found on well-drained, relatively high ground. The semi-subterranean houses constructed by the residents were largely responsible for this requirement.

Table 7 lists by index number the possible site and some comments regarding its suitability as a site.

Thus only 19 of the 379 locations identified on the printout were selected as possible archaeological sites by examination of aerial photography. This represents a 2% ratio. On the other hand, approximately 300 of the potential sites on the printout could be eliminated from consideration on the basis of their location without use of aerial photography. This would yield a 25% ratio of ERTS-identified sites considered possible archaeological sites based on aerial photography.

In the previous section, we compared the number of archaeological sites located by means of ERTS digitally processed data with the number of those sites remaining for consideration after examination of high quality aerial photography of the same area. The best result that can be achieved is that approximately 25% of the sites determined by analysis of ERTS data would be selected by means of aircraft data. This is only after the ERTS-selected sites have been transferred to topographic maps so that sites considered unsuitable because of their unfavorable locations could be eliminated.

Of the twelve sites described by DeLaguna (1947) along the middle of the Khotol River (e.g. not along its tributaries), five were identified as sites on the computer printout. For example Figure 8 shows a vertical

TABLE 7

Index	Map	Comments
3	Nulato (A-5)	close to waterway, clearing
6	Nulato (A-5)	on bank of waterway in clearing
30	Nulato (B-5)	high ground next to stream bank, clearing in trees
32	Nulato (B-5)	located next to river, looks possible
46	Nulato (B-4)	some possibility, a bit low but good location
112	Nulato (A-6)	high ground between two waterways, clearing in trees
117	Nulato (A-6)	near waterway
120	Nulato (A-6)	near waterway, clearing in trees
124	Nulato (A-6)	known site, "Old Fish Camp"
130	Nulato (A-6)	clearing in trees, texture could be house pits
138	Nulato (A-6)	high ground, base of hill on waterway
139	Nulato (A-6)	situated in clearing at base of hill
142	Nulato (A-6)	situated on edge of river
155	Nulato (B-5)	good location, high ground
158	Nulato (B-5)	possible from appearance
222	Nulato (B-5)	high ground next to waterway
226	Nulato (B-5)	high ground next to waterway
236	Nulato (A-6)	texture could be house pits
248	Nulato (A-6)	possible, from appearance
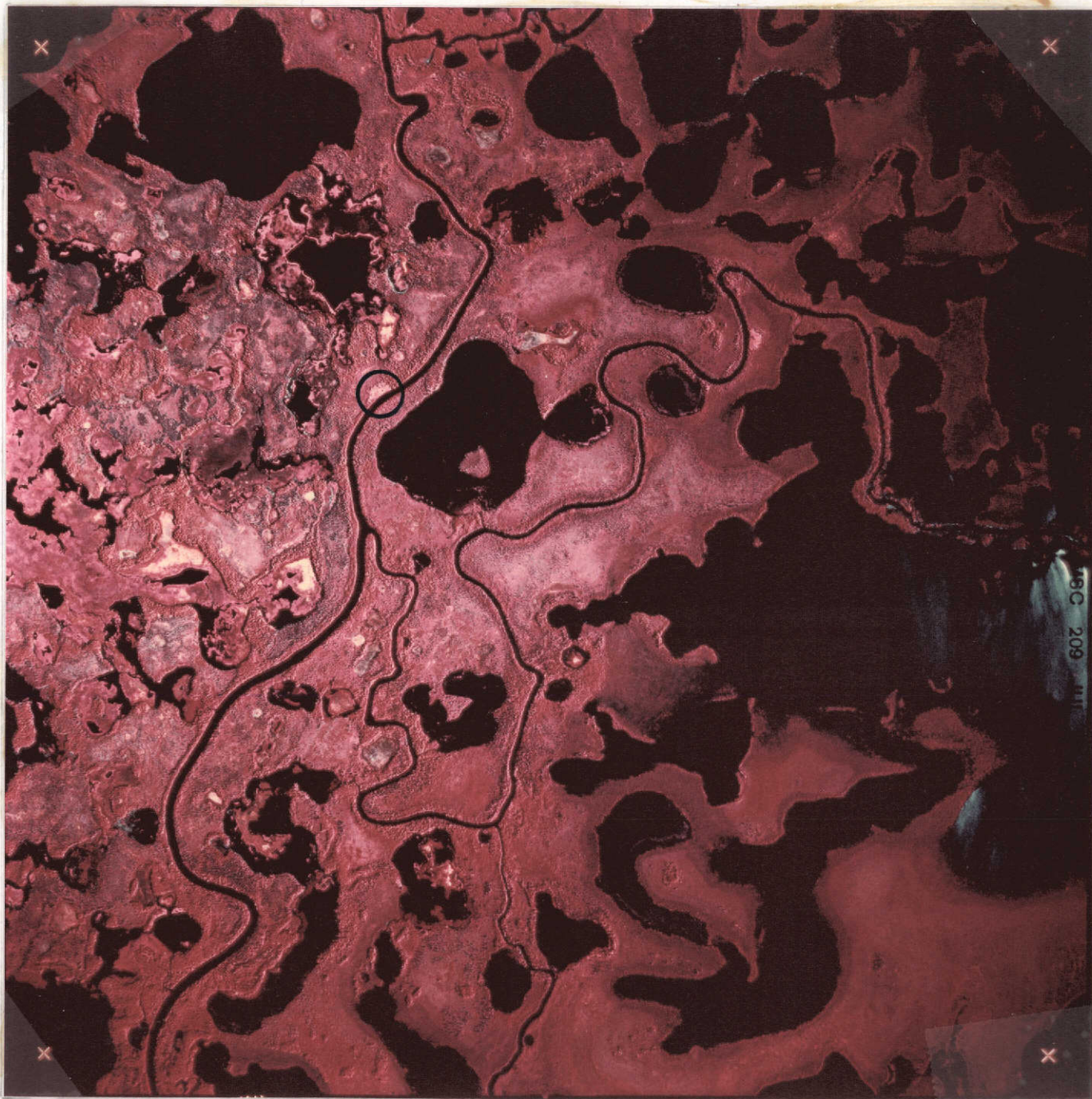
Figure 8. Aerial photograph of archaeological site named "The Mouth
of Cottonwood Creek"

aerial photo of the site named "The mouth of Cottonwood Creek". Figure 9
shows the corresponding portion of the computer printout for this area.
The site was identified as a "4" signature.

As mentioned previously, several potential sites were identified
which were not identified by DeLaguna. One of these is shown in
Figures 10 and 11 where a vertical aerial photograph and corresponding
portion of the digital printout show a very likely former village site
located on a narrow neck of land between the Khotol Slough and a
former length of the slough which has now become a long lake entering
the Khotol Slough approximately two miles from this location. If this
is an archaeological village site, it may have been obscured from
DeLaguna's view by trees growing on the Khotol Slough side.

On the other hand, it is likely that not all potential large
archaeological sites were identified. Half of the sites found by
DeLaguna were not identified on the printout. While it could be argued
that some of these are small, at least one large site, circled on
Figure 12 was not identified. Figure 13 shows a portion of the printout
for this area. This is the site identified as "Latskokat" by DeLaguna.
Note that the signatures in this area are spectrally close to archaeolog-
ical site signatures.

In several instances that a known site was not recognized, a blank
appeared on the printout where an archaeological site signature should
have appeared. In these cases, the combination of intensity levels was
located at a position near the volume occupied by archaeological site
signatures on Figure 3.

Figure 9. Portion of signature printout containing archaeological
site: "The Mouth of Cottonwood Creek"
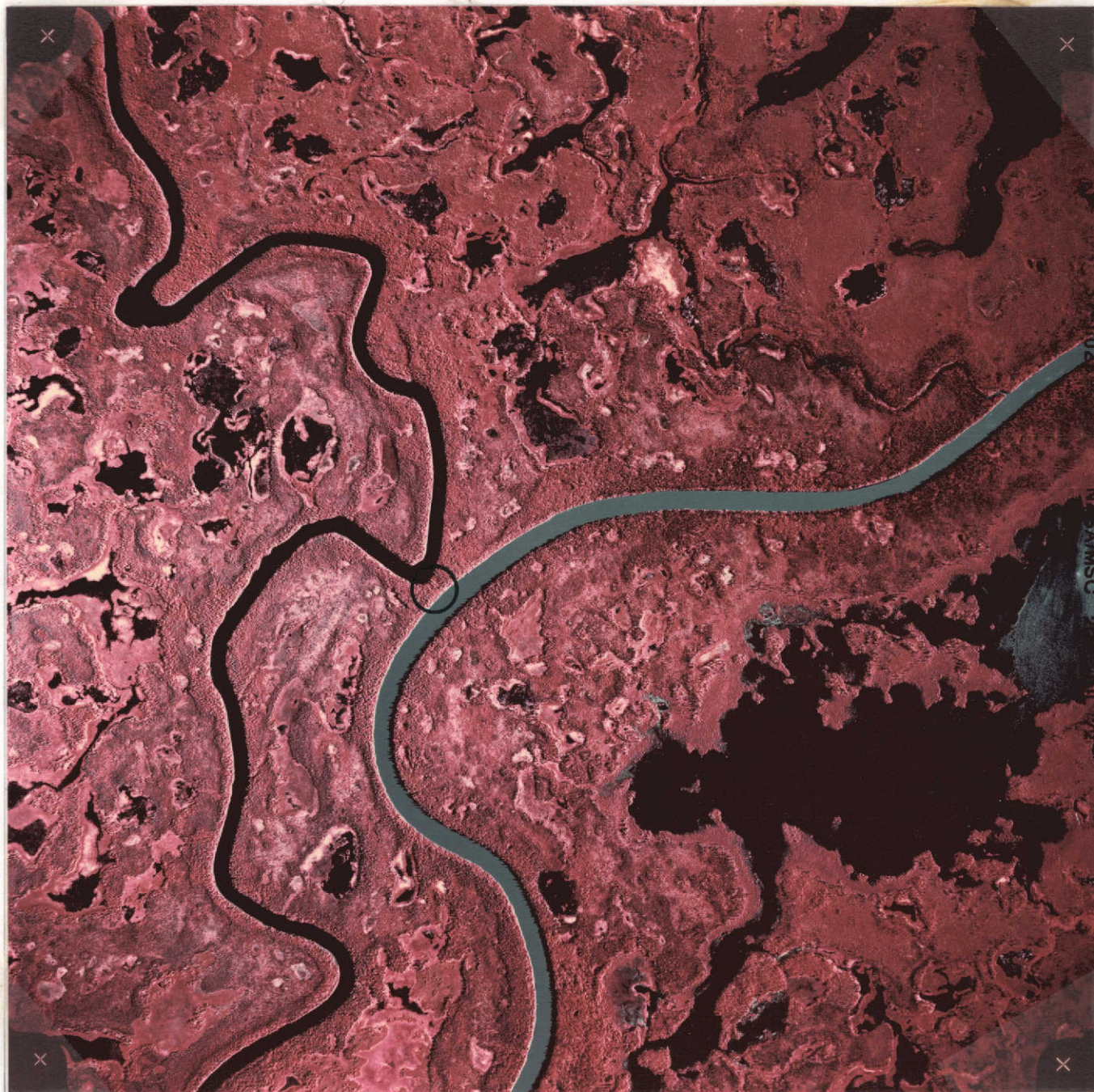
Figure 10. Aerial photograph of location of possible archaeological
site identified by ERTS

TX66

Figure 11. Portion of signature printout showing ERTS-identified
            possible archaeological site
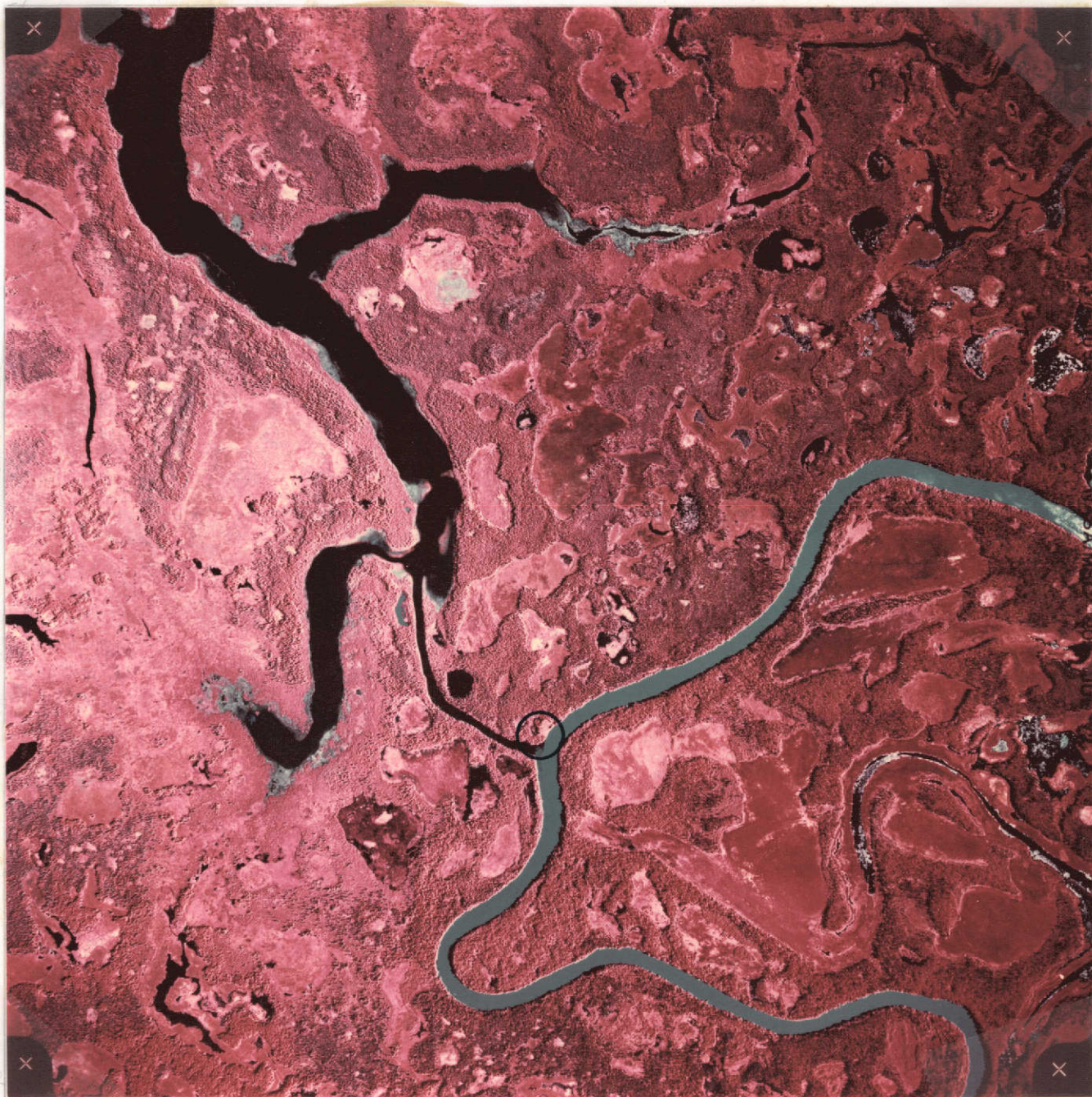
Figure 12. Aerial photograph of large archaeological site not identified on signature printout

Figure 13. Portion of signature printout showing signatures in area of large archaeological site not identified on printout

V. CONCLUSIONS: THE FEASIBILITY OF MAPPING LARGE ARCHAEOLOGICAL VILLAGE
   SITES BY MEANS OF ERTS-1 DATA

The results described in the previous section are encouraging, but

as has been pointed out, considerable interpretation of data is

required to achieve anything approaching useful data. The signatures

1, 2, 3 and 4 are each combinations of one intensity level in each of

bands 5, 6, and 7; yet, with this rigid distinction, over three hundred

potential sites with these signatures were found in the test area of

approximately 450 square miles. Unlikely sites were discriminated

on the basis of location to reduce the number of potential sites to

a reasonable quantity.

Even then, examination of aerial photography showed that many of

the potential sites were very likely not archaeological sites. Finally,

not all known sites of sufficient size to be identified were actually

identified on the digital printout.

Our conclusion is that it is nearly feasible to use ERTS data to

identify large archaeological village sites, and that actual

feasibility could possibly be achieved using the techniques described

in the next section.

VI. RECOMMENDATIONS FOR ADDITIONAL TECHNIQUES TO MAKE POSSIBLE IDENTIFICATION
    OF LARGE ALASKAN ARCHAEOLOGICAL VILLAGE SITES BY MEANS OF ERTS-1 DATA

    A. Elimination of banding and striping in digital data

    These effects are readily seen on ERTS images and digital printouts

of single bands. They result from poor intercalibration among the six

photometers used for each band. The result is particularly troublesome
for signature analysis like that used here where signatures are closely
defined. In the previous section it was reported that in some cases
known sites were represented by blanks on the digital printout resulting
from a combination of intensity levels for that picel which lay outside
the domain of defined signatures.

The intercalibration problem could be corrected manually or by
means of computer program. Although completed too late to be used by
this project, University of Alaska ERTS project No. 1 did construct
a computer program for this purpose. However, it appears that the inter-
calibration ratios actually change within a few kilometers with the
result that the program is only of limited utility. In our particular
case we could compute intercalibration ratios using intensity levels
measured from the Yukon River.

B. Use of scenes from other seasons

1. sun-angle considerations

The scene used was considered to be of high value because it was
obtained very soon after the aerial photography was acquired. Hence, the
latter could be used for interpretation of the former.

Although the scene used was obtained in late August, because of the
high latitude of Alaska, shadows are quite long. Since almost all former
village sites occur in clearings in the forest, they are partly covered
by shadows which obviously play a role in determining their signature.
Data taken near the summer solstice would possess minimum ambiguity

due to this effect. This data was not available to us until after the major portion of the work had been completed.

2. seasonal variations in vegetation

We reported earlier that many of the potential sites identified on the computer printout were easily rejected on the basis of examination of the vertical aerial photography. Generally this was because it could be seen that these areas were low-lying and not well-drained. Although by mid-August these two types of areas have similar spectral characteristics, it may well be that in early June the vegetation in the well-drained areas will become active before vegetation in the low-lying areas because these areas remain cold from melt waters. ERTS digital data from this time period may offer stronger archaeological site signatures than any other season.

VII. OTHER APPLICATIONS OF RESULTS

The method of processing ERTS digital data used here involved producing a general vegetation map. This method is considered valid for generally level topography and could be used for detailed vegetation mapping under these conditions.

An immediate application of this technique would be a detailed forest inventory along Alaska's major rivers. These forested areas are generally flat and because timber along the rivers is accessible, they are of potential commercial value.

To date, a region-wide timber inventory has been made but no data exists on designated areas. In one or two small regions of interior

Alaska timber inventories have been made at considerable cost by analysis

of aerial photography. Although not as precise as photographic

techniques, the ERTS technique is probably on the order of one order

of magnitude cheaper.

VIII. INTEREST BY AGENCIES

We have not yet actively sought funding by other agencies. However,

we did receive a request for a proposal from the National Park Service. A

proposal was submitted for funding using FY 1973 EROS allocations. As the

letter attached as Appendix A details, the work was originally one of 9

proposals selected for funding and was deleted when available funds

limited Park Service EROS activities to three of the nine projects.

IX. FUTURE ACTIVITIES

We feel we were fortunate that NASA should support the seemingly

risky activity of determining the feasibility of locating archaeological

sites by use of ERTS-1 data. The results seem to us to indicate that

this method is nearly feasible. We have suggested additional techniques

which may make ERTS a practical archaeological tool.

We plan to propose to other funding agencies to carry this work

further based on these results.

LIST OF PUBLICATIONS

1. Remote Sensing of Alaskan Archaeological Village Sites - I A Preliminary

    Report, Presented at the 23rd Alaskan Science Conference, Fairbanks,

    Alaska, 1972.   (Published in Preprint form)

2. Remote Sensing of Alaskan Archaeological Village Sites - II Digital

    Analysis of ERTS Data, Presented at the 24th Alaskan Science Conference,

    Fairbanks, Alaska, 1973.

LIST OF REFERENCES

DeLaguna, Frederika (1947) "The Prehistory of Northern North America as

    seen from the Yukon", Memoirs of the Society for American Archaeology,

    No. 3.

Jetté, Julius, S. J. (undated manuscript circa 1910) "On the geographical

    names of the Ten'a", Oregon Province Archives, Gonzaga University,

    Spokane, Washington.

Loyens, William J. (1966) "The Changing Culture of the Nulato Koyukon

    Indians", Ph.D. thesis, University of Wisconsin.

Schwatka, John F., Compilation of Narratives of Explorations in Alaska,

    56th Congress 1st session, Senate, Report No. 1023, April 18, 1900.

    U. S. Government Printing Office.