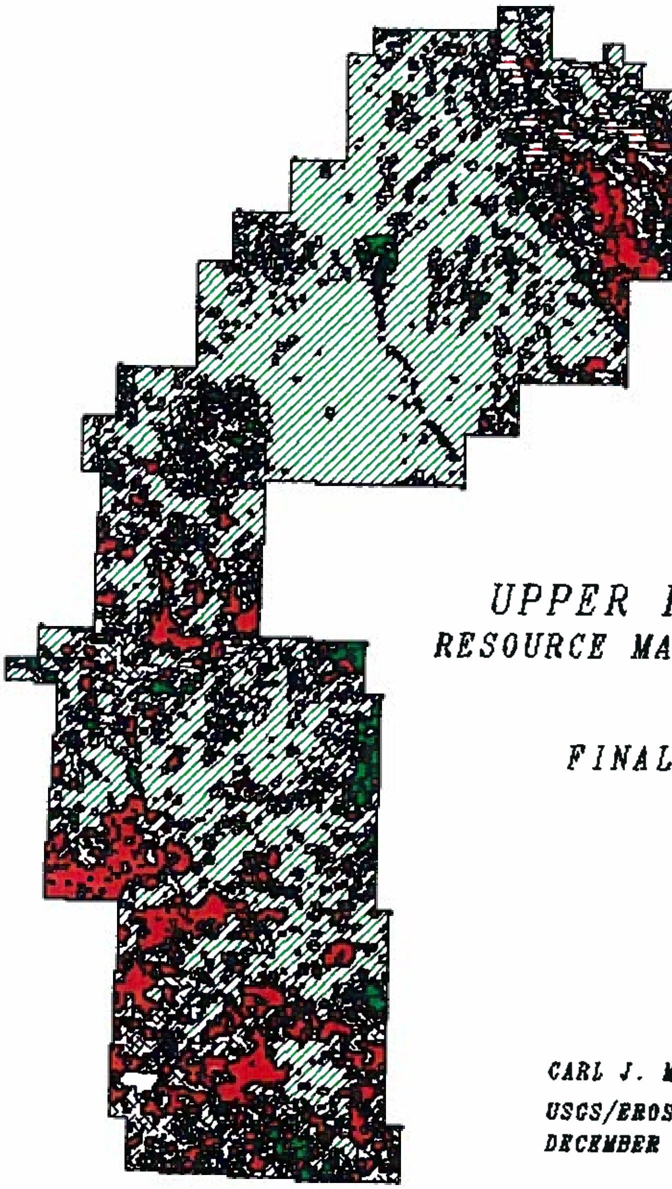

UPPER KUSKOKWIM
RESOURCE MANAGEMENT AREA

FINAL REPORT

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LAND COVER MAPPING OF THE UPPER KUSKOKWIM RESOURCE MANAGEMENT AREA USING LANDSAT AND A DIGITAL DATA BASE APPROACH

By Carl Markon[1/]

ABSTRACT

Digital land cover and terrain data for the Upper Kuskokwim Resource Management Area (UKRMA) were produced by the U.S. Geological Survey, Earth Resources Observation Systems Field Office, Anchorage, Alaska for the Bureau of Land Management. These and other environmental data, were incorporated into a digital data base to assist in the management and planning of the UKRMA.

The digital data base includes land cover classifications, elevation, slope, and aspect data centering on the UKRMA boundaries. The data are stored on computer compatible tapes at a 50-m pixel size. Additional digital data in the data base include: (a) summer and winter Landsat multispectral scanner (MSS) data registered to a 50-m Universal Transverse Mercator grid; (b) elevation, slope, aspect, and solar illumination data; (c) soils and surficial geology; and (e) study area boundary.

The classification of Landsat MSS data resulted in seven major classes and 24 subclasses. Major classes include: forest, shrubland, dwarf scrub, herbaceous, barren, water, and other. The final data base will be used by resource personnel for management and planning within the UKRMA.

This paper is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards or nomenclature.

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[1/]TGS Technology, Inc. Work performed under U.S. Geological Survey contract 14-08-0001-22521.

INTRODUCTION

The Upper Kuskokwim Resource Management Area (UKRMA) encompasses approximately 2.83 million acres of land and water in southcentral Alaska. The Bureau of Land Management (BLM), having jurisdiction over the UKRMA, requested the U.S. Geological Survey's (USGS) Earth Resources Observation Systems (EROS) Alaska Field Office to produce a Land Cover Map of the area to assist in management activities and policy-making processes.

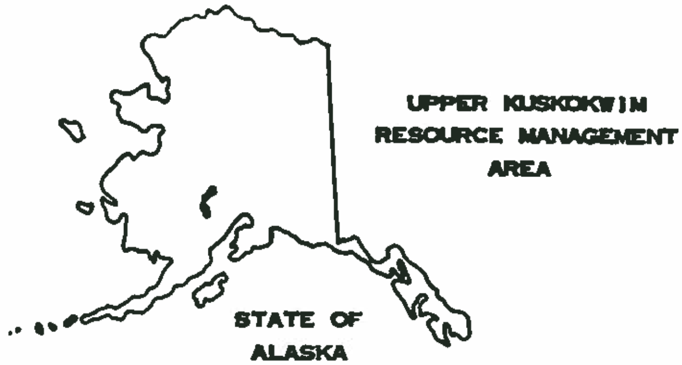
Previous published maps of the area were limited to a 1:7,500,000-scale map by Kuchler (1966) and 1:1,500,000-scale map by Selkregg (1975). Both contain very broad or regional land cover classifications, which lack the detail needed by the BLM. The decision to use a computer-assisted analysis of Landsat multispectral scanner (MSS) data was made because (1) complete coverage of the refuge could be obtained, (2) the level of detail would be adequate to meet most of the BLM's planning and management needs, (3) the work could be completed in a relatively short period of time, and (4) the resulting data base could be integrated with other data bases, in either a vector or raster format. The objectives of this paper are to discuss the methodology used to produce the land cover classifications and accompanying data base and describe the different types of products produced.

STUDY AREA

The UKRMA study area is located approximately 200 miles west of Anchorage, Alaska (fig. 1). The Kuskokwim River, with its predominantly westward flow, borders the study area on the northeast, north, and west. The Stony River runs through the southern portion of the study area, with the Alaska Range bordering the eastern side. Two physiographic provinces occur within the UKRMA: Western Alaska and, to a minor extent in the east, Alaska-Aleutian (Wahrhaftig, 1965). Within these provinces are three land resource areas: Interior Mountain Lowlands, Kuskokwim Highlands, and the Alaska Range. Running roughly northeast to southwest, the Interior Mountain Lowlands are long, relatively narrow plains bordering the Kuskokwim, Stony, and Big Rivers. These areas are low, with poorly drained mineral or organic soils on level to moderate slopes. Permafrost is normally shallow, except near the larger rivers. The Kuskokwim Highlands, flanking either side of the intermountain lowlands to the east and west, includes hills and low mountains up to 600 m. These highlands are characterized by gravelly outwash and till that is covered by a thin layer of silty loess and volcanic ash. Permafrost is normally 25 to 50 cm below the surface mat, but may be deeper, or absent on well-drained morainal soils. The Alaska Range resource area borders the UKRMA on the east and consists of rough, mountainous terrain with elevations in excess of 3,000 m (Rieger and others, 1979). General vegetation identified for the area include: moist tundra, alpine tundra and barren ground, upland spruce - hardwood forest, bottomland spruce - poplar forest, lowland spruce - hardwood forest, and low brush bog and muskeg (Selkregg, 1975).

METHODOLOGY

A digital data base approach was used to produce land cover classifications of the UKRMA. Digital terrain and other ancillary data were incorporated to help stratify the land cover data into more specific types. Aerial photographs and field data were integrated with the digital data to help identify and define the land cover classes.



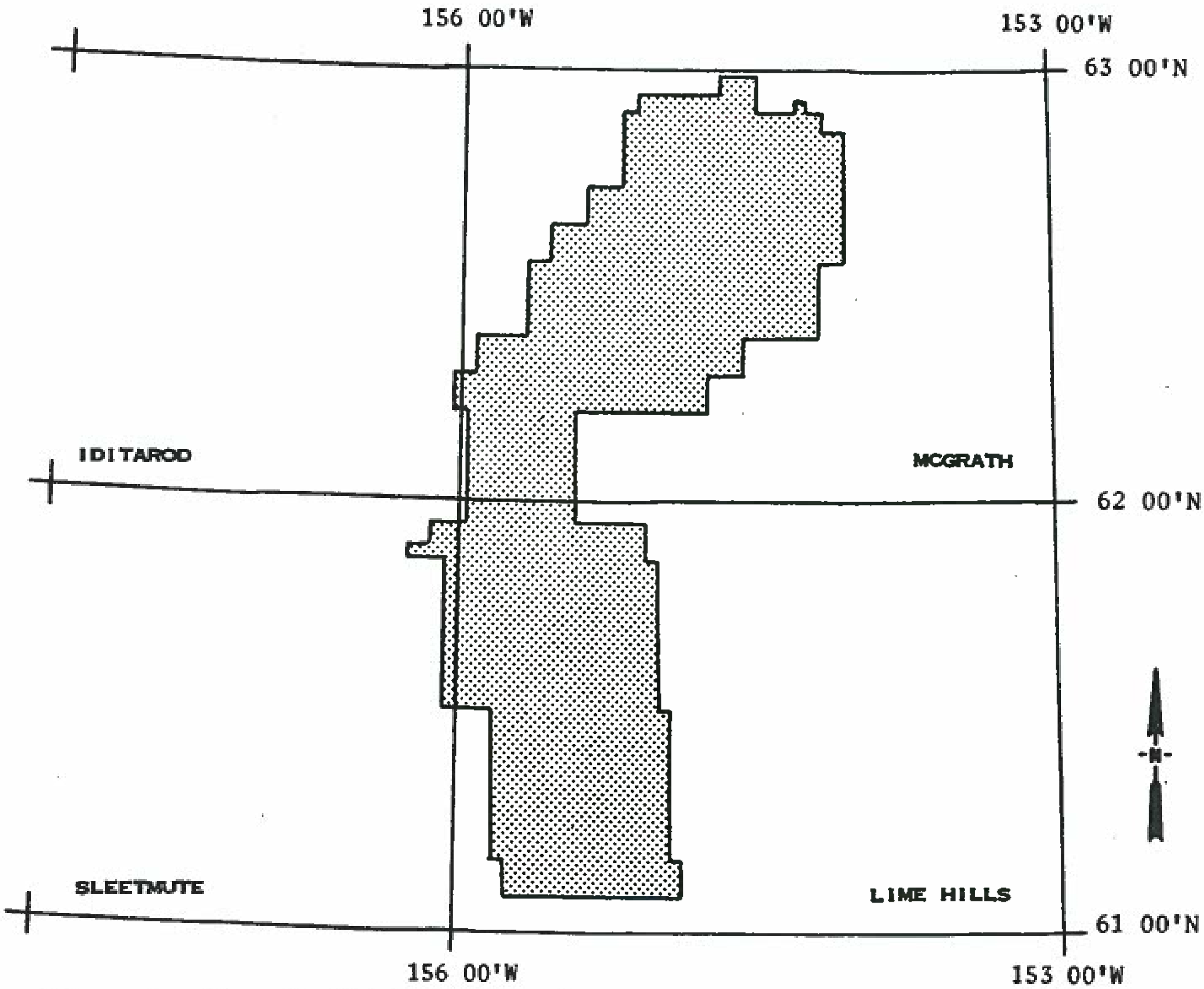


Figure 1.--Upper Kuskokwim Resource Management Area and U.S. Geological Survey 1:250,000-scale quadrangles used.

Data Base Design

The boundaries of UKRMA are contained within four U.S. Geological Survey (USGS) 1:250,000-scale topographic maps (fig. 1). A Universal Transverse Mercator (UTM) projection was used to reference the data. Minimum data resolution was 50 m by 50 m for each picture element (pixel). A schematic diagram of the mapping and data base development process is shown in figure 2.

Data Acquisition

Portions of two Landsat MSS scenes, identification numbers: 85018521081 and 85018521083, taken on September 2, 1984, were obtained to provide complete coverage of UKRMA and surrounding lands. Twenty-two training blocks, sample areas containing representative land cover types, were selected for field study (fig. 3). Block selection was based on visually interpreting the Landsat scenes and identifying them in areas which represented the spectral and floristic variation within each scene. Color-infrared aerial photographs (scale 1:60,000) were obtained for each training block to identify 15 to 20 homogeneous polygons representing the existing vegetation. Ground surveys were performed within each polygon to obtain vegetation cover, structure, and composition.

Field data were entered into an Earth Resources Information System (ERIS), which produces an automated spreadsheet file on the USGS/EROS Anchorage Field Office Interactive Digital Image Manipulation System (IDIMS, ESL, Incorporated, 1981). This spreadsheet allows the analyst to integrate the field data with image-related data (Fleming, 1988; Talbot and others, 1986). For each ground sample site, the spreadsheet listed the associated spectral classes from the preliminary classified Landsat data, with corresponding elevation (in meters), slope (in percent), aspect (in degrees), soils, and surficial geology. This spreadsheet provided clues as to how confusion between spectral classes may be eliminated by using stratification.

Digital elevation data were obtained from the Defense Mapping Agency (DMA). The DMA generated the data by digitizing 200-ft contour lines from the 1:250,000-scale USGS quadrangles and converting them to rectangular grid values. These elevation data were available for each 1:250,000-scale quadrangle associated with the UKRMA.

Digital slope, aspect, and illumination were computed from the digital elevation data. Slope was expressed as percentage slope, that is units of rise per 100 units of run. Aspect values, ranging from 0 to 180 were assigned in a clockwise direction from true north to represent all directions for 0 to 360 degrees. Illumination is based on the Sun's elevation and azimuth at the time each Landsat scene was acquired. The computed data resulted in values from 0 to 255 indicating the amount of light reflecting from the ground surface. For example, low values would indicate shadows and high values would indicate steep slopes incident to the direction of the Sun.

Finally, winter Landsat MSS (WLMSS) data were acquired and registered to the same UTM origins as the summer Landsat MSS data. WLMSS data has been found to be efficient in separating vegetation types because of the different spectral response given for each land cover type and the presence of snow (Fleming, 1988).

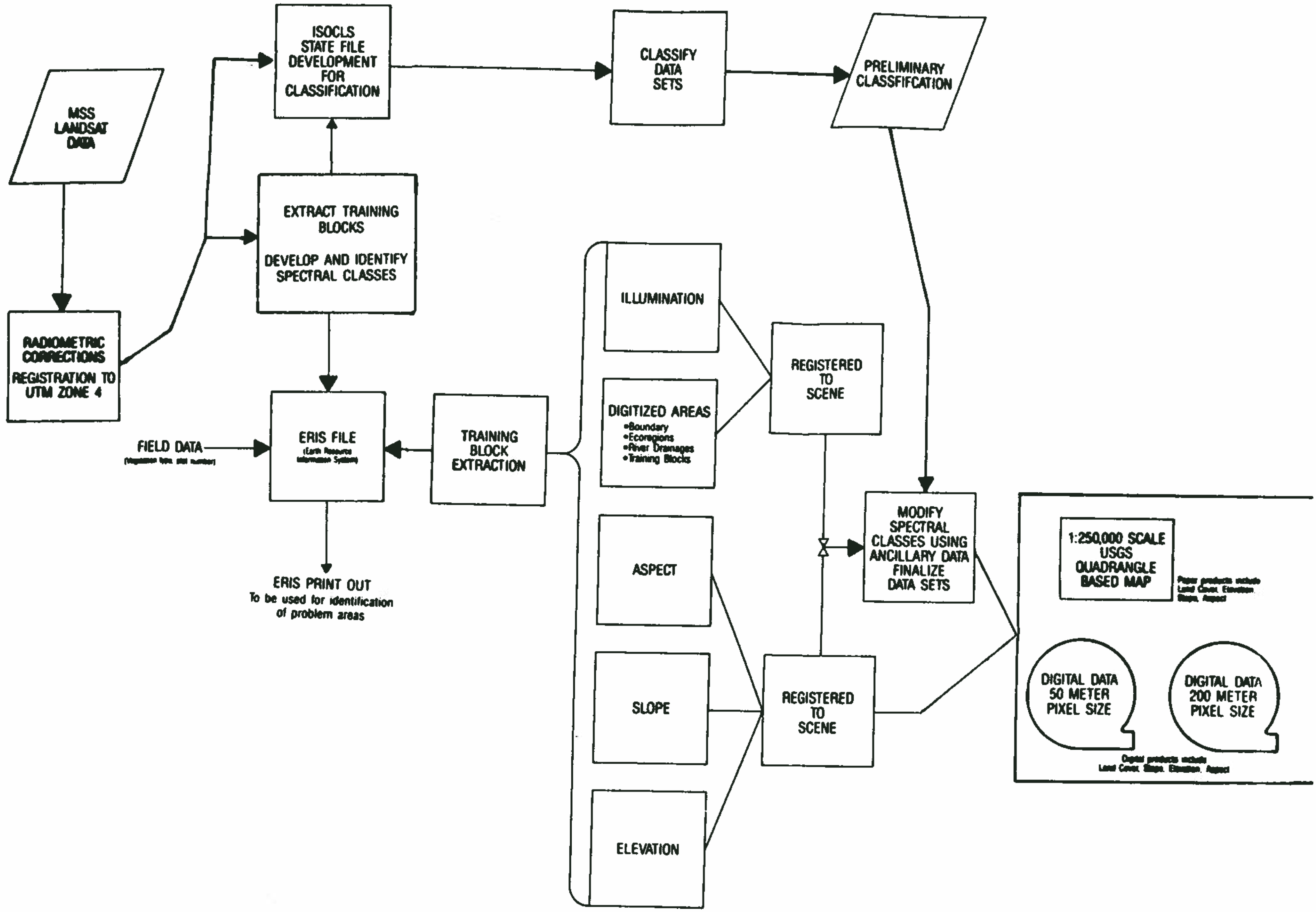


Figure 2.--Schematic diagram of the mapping process to produce the land cover classification for the Upper Kuskokwim Resource Management Area.

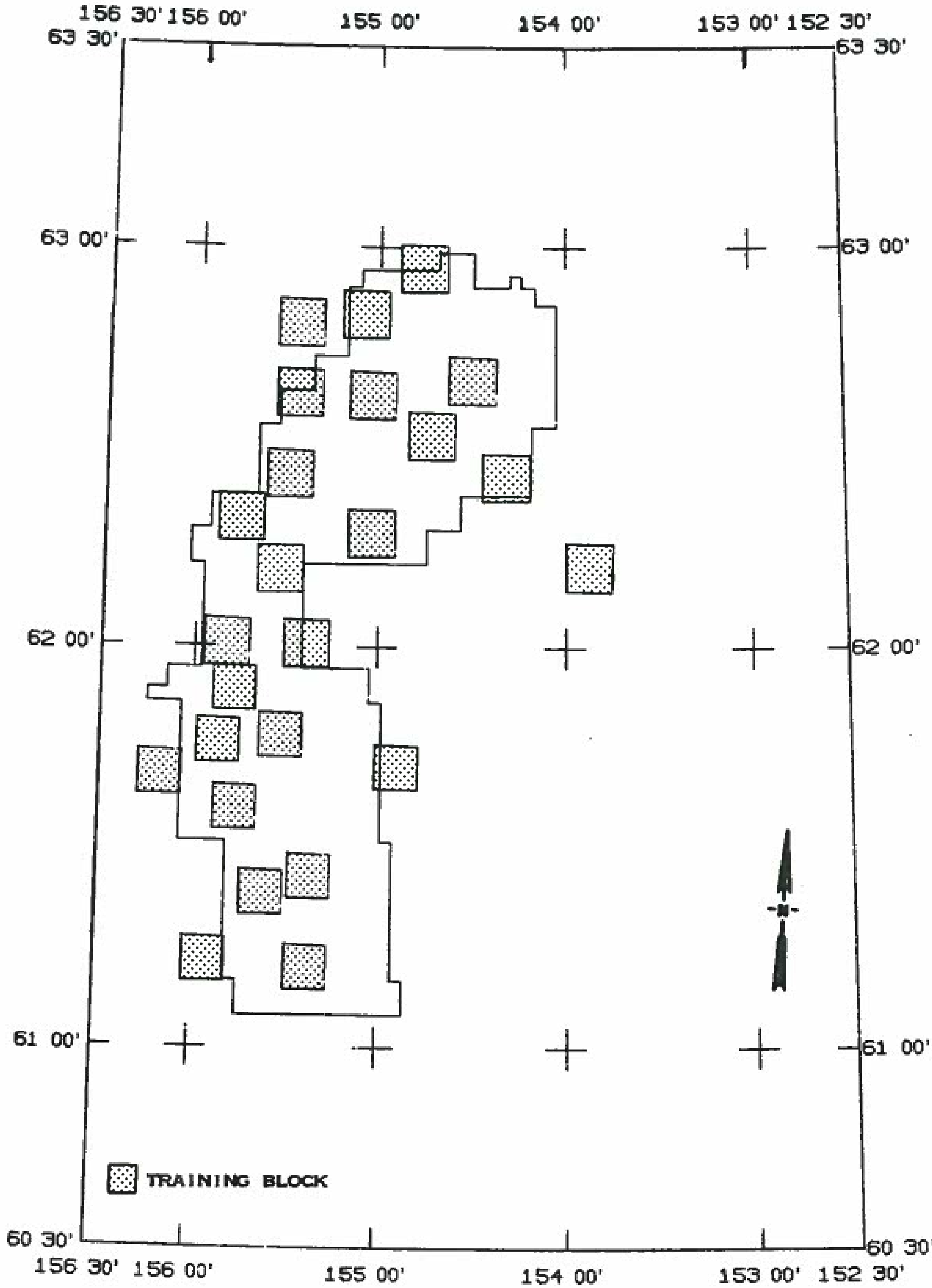


Figure 3.--Location of training blocks used for the Upper Kuskokwim Resource Management mapping project.

PREPROCESSING

Each Landsat scene was acquired in CCT format and reviewed on the USGS/EROS Anchorage Field Office IDIMS. This was done to ensure good coverage was provided and to document the presence of clouds or bad data lines. Control points, used to define second-order least squares polynomial transformation relating UTM northing and easting to the line and sample of the scene, were selected from USGS 1:63,360-scale topographic maps. Criteria for selecting control points required that each point be recognizable on both the topographic maps and the Landsat scene. The mean residual errors associated with the second-order transformation indicated a registration accuracy of +- 0.5 pixels (25 m), depending on scene location (mountain areas with few landmarks versus low lands with lakes and ponds). The final registered scene dimensions were 5,000 lines by 4,000 samples with a UTM origin of 7,000,000 N, 300,000 E, in Zone 5.

DEVELOPMENT OF SPECTRAL STATISTICS

Training statistics used to generate the preliminary classification were derived using a modified cluster-block technique (Fleming, 1975) on the 22 training blocks visited during the field study. The blocks were extracted from each scene and grouped in sets of two or four.

The clustering function ISOCLS (ESL, Incorporated, 1981) was used on each group of training blocks to produce discrete clusters of pixels based on the brightness value of each pixel in each of the four Landsat bands. The function provided a statistical measure of means and standard deviations for each cluster. The statistics were analyzed with redundant or overlapping statistics removed or combined, to form one statistical set which provided an independent estimate of the spectral properties in the scene.

CLASSIFICATION AND SPECTRAL CLASS LABELING

Final spectral statistical files were applied to the training blocks using a maximum likelihood classification algorithm. The algorithm uses a complex mathematical decision rule for evaluating each of the four Landsat bands. The pixel brightness values were compared to the mean and covariance matrix values obtained for each cluster from the statistical file. The maximum likelihood algorithm assigned every pixel in the data set to one of the spectral clusters developed, producing a classification where each pixel represented a vegetation or land cover class.

The classified training blocks were evaluated on a color display monitor. Classes were assigned a vegetation or land cover type name based on interpreted color infrared aerial photographs and field data descriptions. Spectral class inconsistencies within and between training blocks were noted for possible refinement during the post-classification phase. Frequently, spectral classes contained more than one vegetation type due to (1) different vegetation types having similar spectral response; (2) the effects of fires, shadow, and water on the overall reflectance of the vegetation; and (3) variation of the vegetation due to elevation, slope, or aspect changes.

Following the identification of each spectral class in the training blocks, the statistical files were applied to the entire Landsat scene using the same classification algorithm. This produced a preliminary classification of the entire scene. The preliminary classification was reviewed in areas outside the training blocks for consistency and accuracy of the classified vegetation types, with misclassifications noted.

POST CLASSIFICATION REFINEMENT

Preliminary classification accuracies are often low due to similar spectral responses of different land cover types or the effects of variable terrain and moisture presence. To increase the accuracy of the classification, ancillary data were applied to separate classes which were being misclassified. For example, (1) slope and aspect were used to separate shadow from water, (2) elevation was used to separate shrub riparian types from alpine types, and (3) winter data were used to separate shrubland from forested areas. The application of ancillary data on a scene basis was efficient for modifying incorrect classes which occurred over large areas.

RESULTS

Land Cover Classification

The land cover classification for the Upper Kuskokwim Resource Management area resulted in seven major classes: forest, shrubland, dwarf scrub, herbaceous, barren, water, and other. Within these classes are included 24 subclasses (table 1). The most prominent class identified on the refuge was black spruce woodland (40.9%), followed by dwarf shrub sedge lichen (10.88%), wet sedge tussock (9.84%), and black spruce open (8.44%). Cover type descriptions are located in Appendix A. A map showing the final land cover classification is attached as Appendix B.

Digital Products

Final digital products for the UKRMA data base include land cover, elevation, slope, aspect, solar illumination, soils, surficial geology, and management area boundaries. The data were stored on CCT's at a 50-m pixel size. Also included were the original summer and winter Landsat MSS data and ancillary data used during the classification and post-classification process. Appendix C contains CCT storage location and other image-related information for each of the final digital products.

DISCUSSION

The UKRMA incorporated digital data which included summer and winter Landsat MSS data, terrain data, and soils and surficial geologic data. The digital data base approach allows the user to incorporate data from different sources to produce a floristically and ecologically sound map. The data base approach also facilitates changes or updates to the existing Land Cover Map as new data become available. By using all of the different components in the data base, the manager or planner has the flexibility to modify the data to suit his individual needs.

Table 1.--Subclasses with class number and associated number of pixels, acres, and percent of total found for the Upper Kuskokwim Resource Management Area.

DESCRIPTION	CLASS NO.	NUMBER OF PIXELS	ACRES	PERCENT OF TOTAL
FOREST				
White spruce	1	25,554	15,784.71	0.56%
Black spruce - closed	2	76,107	47,011.29	1.66%
Black spruce - open	3	387,253	239,206.18	8.44%
Black spruce - woodland	4	1,838,610	1,135,709.40	40.09%
Mixed spruce - deciduous	5	175,236	108,243.28	3.82%
White/black spruce mix	6	826	510.22	0.02%
Deciduous/tall shrub	7	80,204	49,542.01	1.75%
SHRUBLAND				
Alder	8	35,765	22,092.04	0.78%
Mix	9	263,777	162,935.05	5.75%
DWARF-SCRUB				
Dwarf shrub - sedge lichen	10	499,125	308,309.51	10.88%
Dwarf shrub tundra	11	16,838	10,400.83	0.37%
Dwarf shrub tussock	12	366,838	226,595.83	8.00%
Prostrate dwarf shrub/ Fellfield	13	53,365	32,963.56	1.16%
Lichen shrub	14	25,334	15,648.81	0.55%
HERBACEOUS				
Wet sedge tundra	15	109,649	67,730.19	2.39%
Wet sedge tussock	16	451,198	278,705.00	9.84%
BARREN				
Barren scree	17	71,342	44,067.95	1.56%
Barren floodplain	18	14,620	9,030.77	0.32%
Scarcely vegetated scree	19	238	147.01	0.01%
Scarcely vegetated floodplain	20	5,948	3,674.08	0.13%
WATER				
Clear	21	30,259	18,690.98	0.66%
Turbid/shallow	22	22,132	13,670.94	0.48%
OTHER				
Clouds/snow	23	14,510	8,962.83	0.32%
Shadow	24	21,886	13,518.98	0.48%
TOTALS		4,586,614	2,833,151.47	100.00%

The use of ancillary data such as winter Landsat MSS, soils, surficial geology, elevation, and illumination, facilitated in resolving confusion between classes which were spectrally similar, but floristically different. Winter Landsat MSS data were helpful in discriminating open and closed black spruce and black spruce woodland from each other. It also proved valuable in recognizing burned areas which occurred after the summer Landsat MSS data were acquired. Soils and surficial geology were useful as ecological strata to improve the classification, especially in areas where soils or bedrock dictate plant growth and distribution. Finally, elevation and illumination were useful in identifying classes which are dependent upon terrain conditions.

This land cover classification produced for the UKRMA is the first intermediate-scale map produced for the region. The map shows more detail than either Kuchler (1965) or Selkregg (1979) and increases to 24 the total number of classes available to managers and planners.

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APPENDIX A

UPPER KUSKOKWIM
RESOURCE MANAGEMENT AREA
VEGETATION DESCRIPTIONS

FOREST

For the purpose of this vegetation description, forests are comprised of tree species at least 3 meters tall. Included within this definition are secondary tree growth that is temporarily less than 3 meters in height, i.e. intermittent succession stages, and in some instances, tall willow and/or alder forming dense stands of vegetation along floodplains and on south facing slopes. Major subclasses within the forest class include: 1) white spruce, 2) black spruce - closed, 3) black spruce - open, 4) black spruce - woodland, 5) mixed spruce - deciduous, 6) white/black spruce mix, 7) deciduous/tall shrub.

During the classification, closed, open, and woodland forest subclasses were identified and separated using both summer (September 2, 1984) and winter (February 20, 1979) Landsat multispectral scanner data.

Caution is advised when using the white spruce subclass and in some cases, the open, woodland and mixed forest subclasses. The satellite sensor is not capable of accurately separating white spruce from black spruce. The subclasses indicated on this land cover map were produced by making inferences as to where these classes were most likely to occur based on field data and soils and surficial geological strata. Also, open, woodland, and mixed forest subclasses may at times overlap, depending on the openness of the tree canopy. Finally, woodland or open forest (with 25-35% crown cover range) subclasses, with a preponderance of medium to tall woody shrubs, may be typed as a mixed spruce - deciduous forest.

White spruce -- This forest subclass contains stands of *P. glauca* and is primarily found along floodplains but may occur in other areas. Other tree species that may be found in this type include *Betula papyrifera*, *Populus tremuloides*, *P. balsamifera*, and *Picea mariana*. Because of the occurrence of deciduous tree species, this type may at times be confused with the mixed spruce - deciduous subclass. Other species which may occur in this subclass include: *Betula glandulosa*, *Alnus sp.*, *Salix sp.*, *Ledum groenlandicum*, *Vaccinium sp.*, *Rosa acicularis*, *Sphagnum sp.*, graminoids, and forbs.

Black spruce - closed -- In this subclass the major species is *Picea mariana* although *P. glauca* may also occur. As in the white spruce - closed subclass, crown canopy closure can vary from 60-100%. This subclass is found primarily in the northern portion of the land cover map. Understory species may include: *Ledum groenlandicum*, *Vaccinium sp.*, *Sphagnum sp.* *Betula glandulosa*, *Eriophorum sp.* *Rubus chamaemorus*, lichens, and various graminoids and forbs.

Black spruce - open -- This subclass is common throughout the land cover map and is dominated primarily by Picea mariana with crown closures of 25-60%. Occurring with this type may be small stringers of Betula papyrifera, or Populus tremuloides, especially on hillsides or gentle slopes. Other species associated with this type are: Ledum groenlandicum, Vaccinium sp., Rubus chamaemorus, Betula glandulosa, Larix laricina, Epilobium latifolium, Eriophorum sp., Cladina lichens, graminoids, and forbs.

Black spruce - woodland -- This subclass has an overstory of Picea mariana and is the most common subclass on the land cover map. Crown closure varies from 10-25% and the understory is commonly dominated by ericacous plants and/or sedge forming tussocks. Common shrubs include: Vaccinium sp., Ledum groenlandicum, Empetrum nigrum, Chamaedaphne calyculata, Betula glandulosa, and Spiraea Beauverdiana. Other species include: Sphagnum sp., Alnus sp., Eriophorum sp. (often forming tussocks), fruticose lichens, other graminoids and forbs.

Mixed spruce - deciduous -- This subclass normally has a crown cover of 60-100% with more or less equal proportions of needleleaf and deciduous tree species such as Picea glauca, P. mariana, Larix laricina, Betula papyrifera, Populus balsamifera, and P. tremuloides. Salix alaxensis and Alnus incana may also occur mixed with the tree species, especially along river and stream banks. Other species which may occur in the understory include: Vaccinium sp., Salix sp., Spiraea Beauverdiana, Potentilla fruticosa, Empetrum nigrum, and various graminoids and forbs.

White/black spruce mix -- This is one of the least abundant subclasses in the land cover classification and occurs mainly in a region south of the town of McGrath. This subclass is dominated by Picea glauca and P. mariana with a crown closure of 30-100%. Many of the plant species found in the white and black spruce subclasses occur in this subclass.

Deciduous forest/tall shrub -- This subclass is primarily dominated by hardwood species such as Betula papyrifera, Populus tremuloides, and P. balsamifera. Also occurring are Salix alaxensis and Alnus incana along river and stream banks and Alnus crispa on well drained, southern hillsides.

SHRUB

This vegetation class is predominately composed of deciduous shrubs that provide greater than 25% ground cover and are 1 to 3 meters in height. Two subclasses are identified on the land cover map: 1) Alder and 2) Mix.

Alder -- This subclass is made up of the species Alnus, and may include A. incana, occurring along river and stream courses, and A. crispa, occurring on hillsides and at higher elevations on southern aspects.

Mix -- This subclass is found thoughout the project area with a higher concentration occurring in the central and south central highlands. As the name infers, this subclass is made up of a mixture of different species which may include: small stands of regenerated Betula papyrifera, B. glandulosa, Salix sp. on regenerated burn areas, Salix alaxensis, S. glauca, Alnus crispa, and A. incana. In some areas, pure stands of Alnus sp. or Salix sp. may occur. Other species which may occur in this subclass include: members of the Ericaceae family, Spiraea Beauverdiana, Potentilla fruticosa, Diapensia sp., and graminoids, forbs, and ferns.

DWARF SCRUB

This vegetation class is composed chiefly of deciduous shrubs that are .25 to 1 meter in height and provide 25-100% ground cover. In some cases, the dominate vegetation may be graminoids or lichen but are included in this class due to the shrubs higher life form. There are five subclasses identified on the land cover map: 1) dwarf shrub - sedge lichen, 2) dwarf shrub tundra, 3) dwarf shrub tussock, 4) prostrate dwarf shrub/fellfield, and 5) lichen shrub.

Dwarf shrub - sedge lichen -- This subclass is abundant in the southern portion of the study area and in older burns. It is composed chiefly of ericaceous shrubs, graminoids, and fruticose lichens. Plant species include: Ledum groenlandicum, Vaccinium sp., Arctostaphylos sp., Betula glandulosa, and Salix sp. Graminoids, such as Eriophorum sp. may be found forming tussocks. Fruticose lichens are present in varying degrees.

Dwarf shrub tundra -- This subclass is primarily composed of shrubs, occurring in open areas and on hill sides. The shrub component is normally more dense (50-100%) than the dwarf shrub - sedge lichen subclass. This subclass contains members of the Ericaceae family along with Salix sp., Betula glandulosa, Arctostaphylos sp., Dryas sp., Diapensia sp., graminoids, forbs, and sphagnum.

Dwarf shrub tussock -- The dominate feature of this subclass is the graminoid (normally Eriophorum sp. or Carex Bigelowii) forming tussock. This subclass is locally abundant and common in burn areas. On many sites, scattered Picea mariana, or standing dead spruce snags may be present. The graminoid component of this subclass may occupy 50-90% of the total plant cover. Also associated with this type are: members of the Ericaceae family, Betula glandulosa, Salix sp., Sphagnum sp., other graminoids, and forbs.

Prostrate dwarf shrub/fellfield -- This subclass is found primarily in the uplands at high elevations but can occur on wind swept hill tops and along dry floodplain terraces. In many cases, vegetative height may be less than .25 meters. Common plants found in this type include: Dryas integrefolia, D. octopetala, Lupinus arcticus, Epilobium palustre, E. latifolium, Arctostaphylos rubra, A. ura-ursi, A. alpina, Diapensia sp., and a small amount of graminoids, forbs, and lichens. Bare rock or gravel may also make a sizable portion of this subclass.

Lichen shrub -- This subclass is chiefly composed of fruticose lichens (75-100%) with a small component of shrubs. This type is scattered through out the study area, being more prominent on hill tops and high mountain slopes. Common shrub species include: Vaccinium sp., Salix sp., Ledum groenlandicum, Betula glandulosa, and Arctostaphylos sp.

HERBACEOUS

This class contains species which do not contain significant amounts of woody tissue and normally die back at the end of each growing season. The two major growth forms in this class are graminoids and forbs. Two subclasses are described for the herbaceous class: wet sedge tundra and wet sedge tussock.

Wet sedge tundra -- This subclass is chiefly composed of the genera _Carex_ and _Eriophorum_. It is normally found in areas with very wet (standing water) or wet (saturated) soils condition. This type may also be found in areas which are seasonally saturated (such as old river flood plains during spring flooding) and along lake or pond shorelines. Species found in this type may include: _Carex aquatilis_, _Eriophorum vaginatum_, _E. angustifolium_, _Equisetum sp._, _Potentilla sp._, and various forbs. On moist to wet sites, _Betula glandulosa_, _Chamaedaphne calyculata_, _Andromeda polifolia_, _Oxyccocus sp._, and _Rubus chamaemorus_ may occur.

Wet sedge tussock -- This subclass is composed primarily of _Eriophorum sp._ or _Carex Bigelowii_ forming tussocks. The type is abundant through out the study area, especially in the south. These sites are normally moist to wet and may have a small shrub component such as _Ledum sp._, _Betula glandulosa_, _Vaccinium sp._, and, _Andromeda polifolia_. _Rubus chamaemorus_, _Petasites sp._ and other forbs may occur among the tussocks.

BARREN

In this class, plants are scarce or absent and soil, gravel, and/or rock make up the overall composition. There are four subclasses in this type: 1) barren scree, 2) barren floodplain, 3) scarcely vegetated scree, and 4) scarcely vegetated floodplain.

Barren scree -- This subclass normally has less than 5% plant cover and occurs on higher elevations and steep slopes. _Dryas sp._, _Cassiope tetragona_, and a few grasses and forbs may be present in small protected areas. In some cases, the rock component may be covered with crustose lichens.

Barren floodplain -- This subclass is found on riverine outwash areas and normally has less than 5% plant cover. The class can be found in the low lands as well as in the mountainous areas.

Scarcely vegetated scree -- This subclass is found in mountainous areas with unstable rock or harsh weather conditions. Plant cover is normally 5-30% and may contain _Dryas sp._, _Cassiope tetragona_, _Betula glandulosa_, _B. nana_, _Salix sp._, _Alnus sp._, _Diapensia sp._, and various grasses and forbs. As with the barren scree subclass, the rock component is common and may contain crustose lichens.

Scarcely vegetated floodplain -- This subclass is similar to the barren floodplain subclass except the plant cover may vary from 5-30%. Common plants present may include: _Dryas octopetala_, _Epilobium angustifolium_, _E. palustre_, _Salix sp._, and _Alnus sp._

WATER

This class has two subclasses: clear water and turbid or shallow water.

Clear water -- This subclass includes water which is relatively free of sediment or particulate matter. Lakes and ponds in this class may contain _Nuphar sp._ in the deeper portions and/or _Carex aquatilis_, _Menyanthes trifoliata_, or _Eriophorum sp._ along the shore lines.

Turbid or shallow water -- This subclass includes water which has a large amount of sediment or particulate matter (such as the Kuskokwim River) or shallow lakes and ponds, normally less than one meter deep.

OTHER

This class contains two subclasses: clouds/snow and shadow.

Clouds/snow -- Clouds and snow are combined in this subclass because of their spectral similarity. The Landsat scene used in this study contained a small amount of cloud cover over the central portion of the study area. Snow was present at the higher altitudes in the mountains. This subclass covered less than one percent of the study area.

Shadow -- In this study, shadow was the result of clouds and topographical relief. This subclass represented less than one percent of the study area.

APPENDIX C

The following source data is relevant to all images listed below.

Coverage: Upper Kuskokwim Resource Management Area

UTM Northing	= 7000000	Number of Lines	= 5000
UTM Easting	= 300000	Number of Samples	= 4000
UTM Zone	= 5	Pixel Size (in meters)	= 50
		Tape Format	= IDTRANS

TYPE OF IMAGE	DATA TYPE	EROS FIELD OFFICE TAPE LOCATION	FILE
Landcover	Byte	IDT 1412	4
Elevation	Integer	IDT 1401	3
Slope	Byte	IDT 1401	4
Aspect	Byte	IDT 1401	2
RMA Mask	Byte	IDT 1412	2
RMA Boundary	Byte	IDT 1412	3
Soils	Byte	IDT 1406	2
Illumination	Byte	IDT 1406	1
Surficial Geology	Byte	IDT 1406	3