ARCTIC NATIONAL WILDLIFE REFUGE
LAND COVER MAPPING PROJECT
USERS GUIDE

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INTRODUCTION

Section 1002 of the Alaska National Interest Lands Conservation Act of 1980 (ANILCA, 1980) requires the Secretary of Interior to conduct a continuing study of fish, wildlife, and habitats on the coastal plain of the Arctic National Wildlife Refuge (ANWR). Included in this study is a determination of the extent, location, and carrying capacity of fish and wildlife habitats.

Title III of ANILCA expanded the ANWR from 9,340,000 acres to 18,500,000 acres. Section 304 of the Act requires the Secretary of Interior to "prepare, and from time to time revise, a comprehensive conservation plan" for the refuge. Before developing a plan for the refuge, the Secretary shall identify and describe--a) the populations and habitats of the fish and wildlife resources of the refuge; b) the special values of the refuge as well as any other archeological, cultural, ecological, geological, historical, palentological, scenic, or wilderness value of the refuge; c) areas within the refuge that are suitable for use as administrative sites or visitor facilities...; d) present the potential requirements for access with respect to the refuge...; and e) significant problems which may adversely affect the populations and habitats of fish and wildlife identified and described..." (ANILCA, 1980). Vegetation, water, and terrain (elevation, slope, and aspect) are the components of habitat and can be used in the determination of the above requirements.

The U. S. Fish & Wildlife Service (USFWS) has the responsibility for collecting the resource information to address the research, management, development and planning requirements identified in Section 304. Because of the brief period provided by the Act for collecting the resource data, data collection, habitat mapping, and habitat assessment, the USFWS in cooperation with the U. S. Geological Survey's EROS Field Office, used digital Landsat multispectral scanner data (MSS) and digital terrain data. A computer assisted digital analysis of Landsat MSS data was used because coverage by aerial photographs was incomplete for much of the refuge and because the level of detail, obtained from the analysis of Landsat data, is adequate to meet most USFWS research, management and planning needs. Relative cost and time requirements were also factors in the decision to use the digital analysis approach.

OBJECTIVES

The primary objectives of the mapping project were to:

1) produce digital land cover/terrain classifications for the ANWR, using digital Landsat and terrain data.

2) provide registered Landsat data for the entire study area defined as the ANWR and the Porcupine River basin in the Yukon Territory,Canada.

3) provide other derivative products and output products as required.

The primary objectives of this user guide are to give a brief discussion of the methodology used and describe the different types of data products produced.

AREAS OF COVERAGE

The ANWR consists of approximately 18.5 million acres of land and water in the northeastern corner of Alaska. The northwest and southeast latitude/longitude coordinates of the mapped area are 71 30'/150 30' and 65 30'/140 30' respectively. The entire study area covers roughly 6 degrees of latitude and 10 degrees of longitude. Portions of 11 Landsat scenes (Table 1) were required to provide complete coverage of ANWR and the surrounding areas (Figure 1). An additional nine Landsat scenes were aquired to provide coverage of the Porcupine River Basin in Canada (Table 2).

METHODOLOGY

A computer compatible tape (CCT) was obtained for each Landsat scene covering refuge lands. The Landsat scenes were radiometrically and geometrically corrected (registered to a 50-meter Universal Transverse Mercator [UTM] grid) and the boundaries of the refuge and the corresponding 1:250000-scale USGS quadrangles digitized. This made it possible to summarize land cover information for each quadrangle and the refuge as a whole. Training blocks (sample areas containing representative land cover types) were selected for field study, and training statistics were derived from them. Figure 2 shows the location of the training blocks used in this study. A modified clustering technique was used to generate initial spectral classifications, using the EROS Field Office computer system (HP-3000) and IDIMS software.

TABLE 1. Landsat scenes acquired to cover the Arctic National Wildlife Refuge.

SCENE NUMBER	SCENE ID NUMBER	DATE	UTM EASTING	UTM NORTHING	NUMBER OF LINES	NUMBER OF SAMPLES	UTM ZONE	PATH-ROW
1	21633-20531	13 July '79	Unknown	Unknown	Unknown	Unknown	6	79-10
2	2570-20462	14 Aug. '76	Unknown	Unknown	Unknown	Unknown	6	78-11
3	21634-20592	14 July '79	370000	7760000	5000	3000	6	80-11,80-12
4	22387-20445	5 Aug. '81	384400	7800000	7240	4050	6	77-11,77-12
5	21305-20183	19 Aug. '78	360000	7500000	3900	3000	6	75-12
6	31636-20533	27 Aug. '82	480000	7600000	3600	3200	6	77-14
7	2583-20174	27 Aug. '76	389900	7657900	4150	2880	7	73-12
8	2927-20135	6 Aug. '77	390000	7700000	3000	2600	7	75-11
9	22386-20391	4 Aug. '81	A 460000	7800000	7200	3600	6	76-11,76-12
	22386-20391	4 Aug. '81	B 336000	7790000	7505	3477	7	76-11,76-12
10	22387-20445	5 Aug. '81	430000	7550000	3100	3100	6	77-12
11	2583-20181	27 Aug. '76	356200	7549950	3415	4050	7	73-13

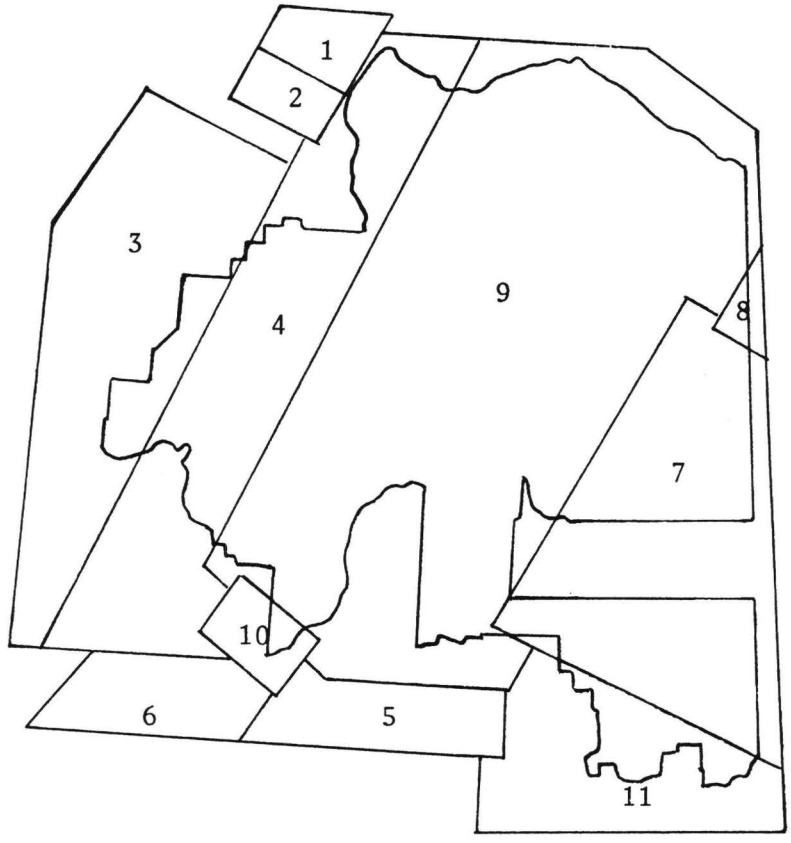


Figure 1. General location of the Landsat scenes used to map the Arctic National Wildlife Refuge.

TABLE 2. Landsat scenes acquired to cover the Porcupine River Basin.

SCENE NUMBER	SCENE ID NUMBER	DATE	UTM EASTING	UTM NORTHING	NUMBER OF LINES	NUMBER OF SAMPLES	UTM ZONE	PATH-ROW
1	20203-20133	13 Aug. '75	570000	7710000	1400	1000	7	71-11
	20203-20133	13 Aug. '75	370000	7740000	4800	1400	8	71-11
2	20203-20140	13 Aug. '75	510000	7660000	4200	2400	7	71-12
	20203-20140	13 Aug. '75	375000	7660000	4600	2700	8	71-12
3	20203-20142	13 Aug. '75	470000	7520000	4600	3400	7	71-13
	20203-20142	13 Aug. '75	360000	7490000	4200	1800	8	71-13
4	20203-20145	13 Aug. '75	460000	7340000	4000	3000	7	71-14
5	21315-19333	29 Aug. '78	440000	7500000	4400	2800	8	67-13
6	21315-19335	29 Aug. '78	390000	7360000	3000	3800	8	67-14
7	20921-19410	31 July '77	350000	7350000	2800	2400	8	69-14
8	22506-20082	9 Aug. '80	360000	7570000	2800	3800	8	70-12
9	22056-20085	9 Aug. '80	350000	7460000	4000	3000	8	70-13

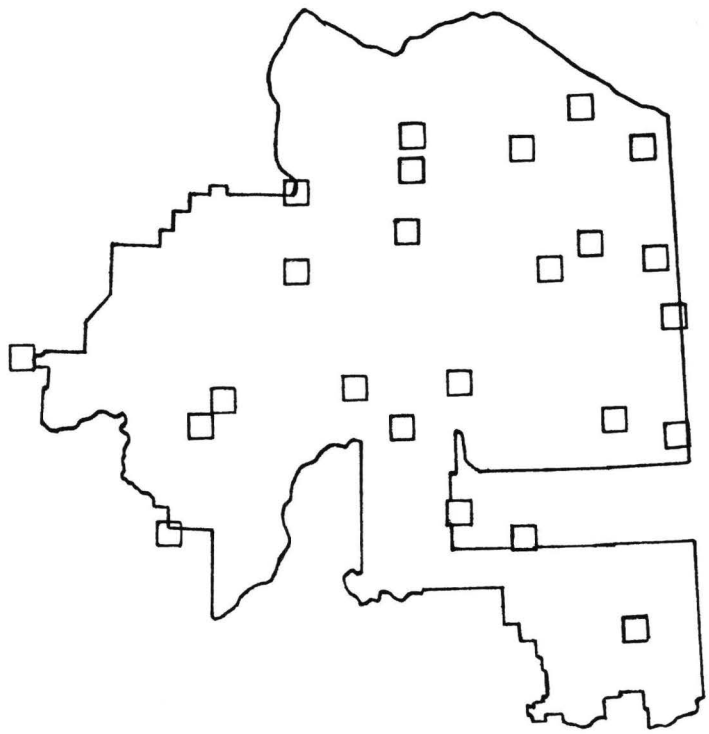


Figure 2. Location of the training blocks used to collect field data and develop training statistics for Landsat scene classification.

Field data on vegetation cover, structure, and composition were collected in each training block to identify land cover types corresponding to computer-derived spectral classes. Final land cover classifications, designated by USFWS personnel, were produced after applying stratification techniques to improve classification accuracy. Land cover classifications were merged with digital terrain data derived from 1:250,000-scale USGS quadrangles to improve classification accuracy and to make possible the production of additional resource data products displaying topographic variables such as elevation, slope, and aspect, either singularly or in combination. The specific procedures used in producing land cover/terrain classifications and output products are detailed in Appendix A.

Land cover classifications covering the 1:250,000 USGS quadrangles were extracted from each Landsat scene (where applicable) and mosaicked together. Landsat scenes used for each quadrangle and a general schematic of what part of the quadrangle a particualar scene covered is shown in Appendix B. Further enhancement was applied to the classification on a quadrangle by quadrangle basis using terrain data and information obtained from USFWS personnel. A schematic diagram of the mapping process is shown in Figure 3.

USFWS personnel worked with EROS personnel to conduct the digital analysis required to produce land cover classifications for the refuge and coordinated with USFWS Information Resource Management personnel to ensure that the digital data were compatible with the USFWS geobased information system.

PRODUCTS

The following products were produced for the mapping project:

1) Land cover classifications of the refuge and surrounding areas. This included hard copy ink jet plots of the land cover in the refuge for 12 1:250,000-scale USGS quadrangles.

2) Acreage estimates for each land cover type in the refuge for each 1:250,000-scale USGS quadrangle.

3) Computer tapes of all raw and registered Landsat scenes.

4) Computer tapes containing land cover and terrain data classifications.

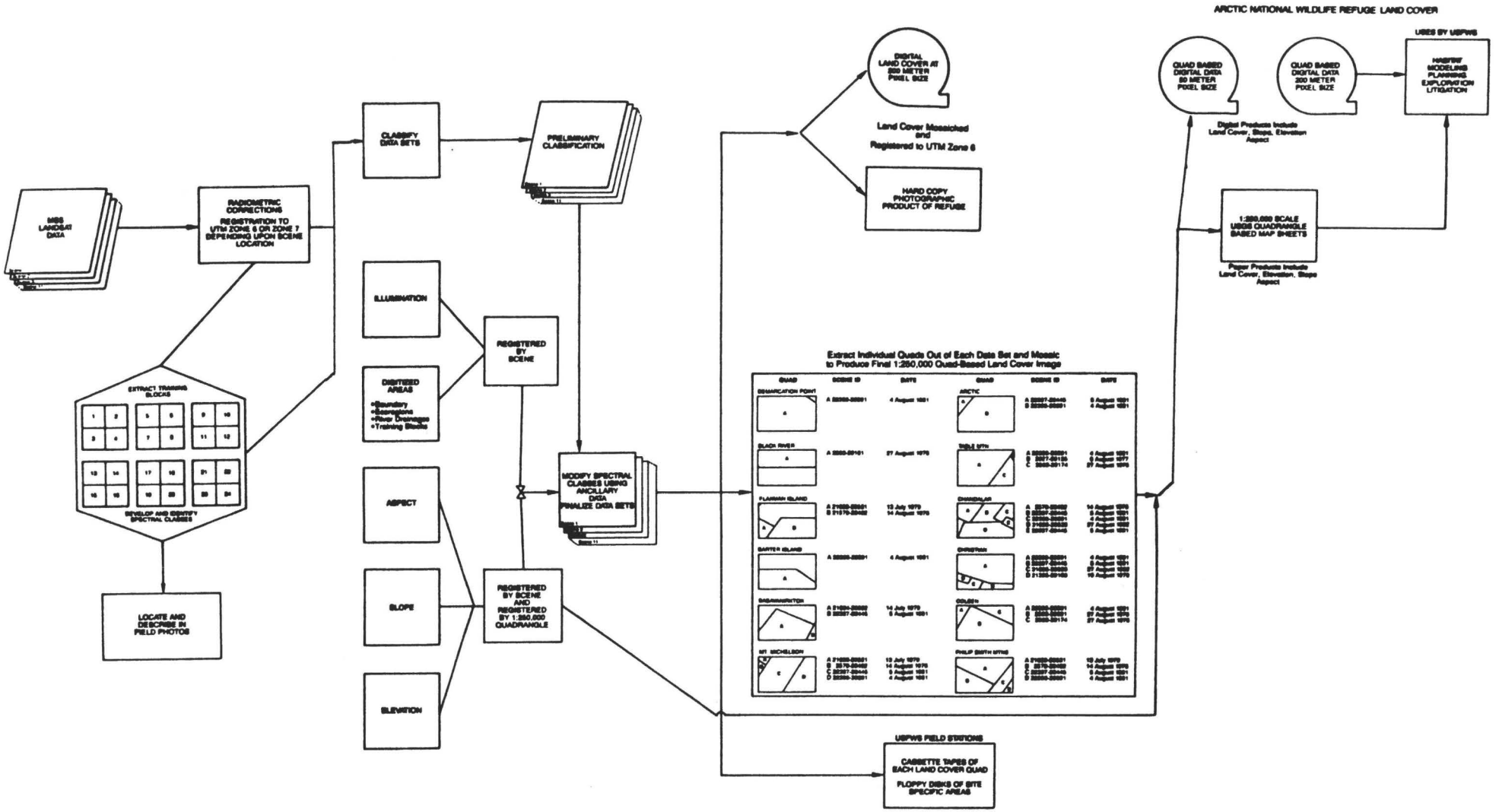


Figure 3. A schematic diagram of the mapping process used to produce the land cover classification of the Arctic National Wildlife Refuge.

5) Computer tapes of resampled land cover and terrain data.

6) Computer tapes of land cover classifications for Yukon Flats reprocessed to a 50-meter pixel grid.

7) Enhanced and registered Landsat mosaic for each UTM zone within the refuge at a 50-meter pixel grid.

8) Elevation, slope, and aspect ink jet plots for each 1:250,000 USGS quadrangle.

9) This users guide.

PRODUCT DESCRIPTIONS-HARD COPY

LAND COVER CLASS DESCRIPTIONS

Based on information acquired in the field, discussions with USFWS personnel, and Landsat spectral discrimination, five major land cover classes were recognized: Forest, Scrub, Herbaceous, Scarcely Vegetated, and Other. Included in these major classes are 23 subclasses (Table 3). A complete description of each of the major classes and subclasses is in Appendix C.

Acreage estimates for each land cover class within the refuge were summarized for each 1:250,000 USGS quadrangle and are listed in Table 4. Final hard copy land cover maps were produced for each 1:250,000 USGS quadrangle in the form of Applicon ink jet plots. Each map contained collar information which included: map title, a list of vegetation classes, locational diagram of the map with respect to the refuge, scale bar and latitude/longitude tick marks. Each land cover class was depicted on the map as a color. The color scheme used was based on input from USFWS and USGS/EROS personnel.

TERRAIN CLASS DESCRIPTIONS

Terrain class maps were produced from the elevation, slope, and aspect digital data and produced for each USGS 1:250,000 quadrangle. Elevation classes were broken into the following catagories (in meters): 0-76, 77-152, 153-304, 305-456, 457-610, 611-762, 763-914, 915-1066, 1067-1218, 1219-1271, 1272-1524, 1525-1676, 1677-1829, 1829 and higher. Slope classes were broken into 0-2%, 3-5%, 6-10%, 11-15%, 16-25%, 26-40%, 41-70%, and 71% and higher. The aspect classes were broken into the four cardinal directions: north, south, east, and west. All of the maps contained the water classes and the elevation and aspect maps contained the 0-2% slope class. Collar information included: map title, scale, locational diagram, map legend, latitude/longitude, and tick marks.

TABLE 3. List of land cover subclasses used during the mapping process.

CLASS NUMBER	SUBCLASS
0	Background
1	Closed Needleleaf
2	Open Needleleaf
3	Needleleaf Woodland
4	Mix Forest
5	Deciduous Forest/Tall Shrub
6	Alluvial Deciduous Scrub
7	Dry Prostrate Dwarf Scrub
8	Moist Prostrate Dwarf Scrub
9	Mesic Erect Dwarf Scrub
10	Very Wet Graminoid
11	Wet Graminoid
12	Moist/Wet Tundra Complex
13	Moist Graminoid Tussock
14	Barren Floodplain
15	Barren Scree
16	Scarcely Veg. Floodplain
17	Scarcely Veg. Scree
18	Clear Water
19	Shallow Water
20	Offshore Water
21	Clouds/Snow/Ice
22	Shadow
23	Roads

TABLE 4. Acreage estimates for each land cover class in the refuge summarized by 1:250,000 USGS quadrangle.

CLASSIFICATION	FLX	BTI	SAG	MTM	DEM	PSM	ARC	TAB	CHA	CHR	COL	BKR	TOTAL
Closed Needleleaf	0	0	0	0	0	1,068	9,393	17,456	11	15,986	235,179	35,594	314,687
Open Needleleaf	0	0	0	0	5,227	3,561	79,976	202,921	228	192,328	755,590	135,265	1,375,096
Needleleaf Woodland	0	0	0	0	0	2,858	172,909	131,506	22,716	507,886	5,710	0	843,585
Mix Forest	0	0	0	0	0	0	0	0	0	0	177,933	37,742	215,675
Deciduous Forest/Tall Shrub	0	0	0	16,514	0	0	0	968	0	0	131,091	74,949	223,523
Alluvial Deciduous Scrub	0	0	0	1,963	353	532	574	11,245	0	0	256	0	14,924
Dry Prostrate Dwarf Scrub	1,415	431	4,751	268,672	352,433	109,543	488,165	568,287	32,418	46,317	22	0	1,872,453
Moist Prostrate Dwarf Scrub	8,090	30,094	111	281,199	402,614	916	5,750	25,989	23	145	15	0	754,946
Mesic Erect Dwarf Scrub	23	66	63,561	342,490	517,812	334,858	846,196	1,508,704	170,498	500,507	441,154	87,814	4,813,684
Very Wet Graminoid	1,540	1,546	862	1,067	3,282	4,511	0	1,604	0	0	0	0	14,412
Wet Graminoid	58,512	36,016	4,714	55,068	197,385	14,229	0	6	0	0	68	0	365,998
Moist/Wet Tundra Complex	11,521	36,350	237	227,150	230,301	209	2,723	0	0	0	0	0	508,491
Moist Graminoid Tussock	1,064	2,008	19,534	435,919	255,407	121,980	206,586	365,600	9,975	71,396	1,383	0	1,490,853
Barren Floodplain	13,079	5,868	5,803	29,420	58,567	16,863	4,897	5,223	389	341	3,929	253	144,632
Barren Scree	0	0	15,365	281,922	313,410	316,090	323,757	65,071	8,418	10,957	1,356	2,194	1,338,539
Scarcely Vegetated Floodpln.	6,550	536	5,000	31,127	15,690	14,887	28,282	20,789	32	5,179	2,951	166	131,188
Scarcely Vegetated Scree	0	0	26,914	398,403	274,384	180,994	672,335	272,054	8,528	17,496	25,885	4,611	1,881,603
Clear Water	10,074	3,190	376	8,774	7,472	4,339	28,128	4,732	53	8,594	19,044	1,919	96,696
Shallow Water	0	0	1,602	2,055	0	9,045	0	0	0	0	0	0	12,702
Offshore Water	23,253	37,999	0	16,178	32,659	0	0	0	0	0	0	0	110,089
Clouds/Snow/Ice	0	41	30,892	53,325	52,703	160,657	7,991	2,995	0	0	1,377	3,135	313,117
Shadow	0	0	74,578	263,466	0	615,873	392,669	164,075	13,669	2,705	373	11,613	1,539,021
Roads	0	0	0	0	176,589	4,663	0	0	0	0	0	0	181,252
TOTAL	135,123	154,145	254,299	2,714,712	2,896,288	1,917,677	3,270,331	3,369,226	266,958	1,379,837	1,803,316	395,256	18,557,167

OTHER PRODUCTS

Transparencies and hard copy photographic prints were produced of the the land cover data. The land cover was resampled to a 200-meter pixel size, registered to UTM Zone 6 and mosaicked together to form one image of the entire study area. These data were then used to make a film transparency and associated prints.

The various Landsat MSS scenes used for the mapping project were enhanced, cross-edge matched and mosaicked together for UTM Zones 6 and 7. A false color composite of each zone was also produced in transparency and print form.

Photographic products of land cover or the Landsat mosaics may be purchased from USGS/EROS.

PRODUCT DESCRIPTIONS-DIGITAL

GENERAL

Digital data are stored at USGS/EROS on CCT's in either an IDTRANS or TRANSFER format. Digital data stored in the IDTRANS format are used at USGS/EROS for internal processing. The TRANSFER format is usually used when data are shipped to other U.S. government agencies or the private sector. Images are generally written on a TRANSFER tape with one image line per record and one image per file. Images may be band-by-band or line-by-line. If the data format is floating point, either a Hewlett-Packard 3000 or IBM format may be specified. Data may be read onto the tape at either 1600 or 6250 bits/inch (bpi). All data relating to this project have been delivered to USFWS at 1600 bpi using the Hewlett-Packard 3000 floating point format.

An attempt was made to standardize the pixel size and UTM origins of the data. For this project most, if not all, of the final data sets were produced at two different pixel sizes: 50X50 meter and 200X200 meter. Pixel sizes were predetermined by the USFWS prior to the finalization of the land cover classification. UTM origins were based on the location of the land cover or terrain data (UTM zone and 1:250,000 USGS quadrangle), pixel size, and image size. Each of the 1:250,000 USGS quadrangle based data had its own origin i.e. all of the land cover and terrain data for the Barter Island quadrangle had the same origin. Also all of the mosaicked data which covered the same area had the same origin. All of the data which has been transfered to the USFWS covered under the Interagency

Service Agreement is summarized in Appendix D. This summarization contains image name, data type, number of lines and samples, UTM origins and pixel size. One exception to the above information is a set of data stored on two Remote Image Processing System (RIPS) 8 inch diskettes. These diskettes contain land cover classifications of each of the 23 training blocks. These data were requested by the USFWS and were extracted from the final land cover classification.

LAND COVER

The land cover images contain up to 23 different classes (Table 3). Since some of the classes only occur in certain ecological regions not all of the classes will occur in each image. The data is byte data. The lowest class, 0, is a background or fill class. The class descriptions corresponding to each class number may be found in Appendix C.

ELEVATION DATA

The digital elevation data were derived from digital terrain data created by the Defense Mapping Agency (DMA). The DMA generated the data by digitizing contour lines, spot elevations, and stream and ridge line data from the 1:250,000-scale USGS quadrangles. The contour intervals range from 50 to 200 feet. These data were then converted to a rectangular grid of values, producing elevation estimates spaced every 0.01 inches on each 1:250,000-scale map (approximately 200 feet on the ground). The data are integer data and can range in values from 0 to about 3000 meters. The data is recorded in one meter increments.

SLOPE DATA

The slope data were computed using the digital elevation data. Slope is computed as percent slope, i.e. units of rise per 100 units of run. The data is byte data and is recorded in one percent increments. Values can range from 0 to 255.

ASPECT DATA

The aspect data were computed using the digital elevation data. Aspect is computed clockwise from north in degrees. The data are byte data with values from 0 to 180: 0 and 180 = north, east = 45, south = 90, and west = 135. Values increase in two degree increments.

ACKNOWLEDGEMENTS

This project was funded by an interagency service agreement between the U.S. Fish and Wildlife Service and the U.S. Geological Survey/EROS Anchorage Field Office, contract number 14-16-0007-83-6008. Field and botanical assistance was provided by Steve Talbot, Mark Shasby, and Larry Strong. Major land cover classification of the Arctic coastal plain portion of the project was accomplished by Larry Strong. Appreciated are David Carneggie and Mark Shasby for their support and review of this report.

REFERENCES

ANILCA, 1980. Alaska National Interest Lands Conservation Act, Public Law 96-487, Washington, D.C.

ESL Incorporated, 1981. IDIMS Functional Guide, Technical Manual ESL-TM705. ESL Incorporated, Sunnyvale, California. Vol. I, 716 p., Vol. II, 319 p.

APPENDIX A

PROCEDURES FOR LAND COVER CLASSIFICATION USING LANDSAT CCT'S

Preprocessing

1. Enter Landsat Data (CCT format) into IDIMS
2. Display and select Landsat subscenes
3. Perform radiometric corrections
   a. Destrip to correct for detector miscalibration
   b. Fix bad data lines
4. Perform geometric corrections
   a. Select control points from Landsat data and maps for image registration
   b. Digitize control points and map boundaries
   c. Generate transformations and rotate Landsat scenes
   d. Register Landsat image to 50 meter UTM grid
5. Produce strata mask for study areas
6. Digitize refuge boundaries
7. Mosaic and register DEM data

Image Training and Classification

1. Select training blocks for study area in each Landsat scene
2. Apply IDIMS clustering algorithm (ISOCLAS)
3. Produce statistics of the spectral classes within the training blocks
4. Produce photographic image of each Landsat training block and color coded cluster map
5. Prepare for field investigations
   a. Acquire aerial photographs of cluster blocks for annotation in field
   b. Develop strategy for aerial reconnaissance and on-the-ground investigations

APPENDIX A

6. Field verification

   a. Describe land cover type associated with each cluster class
   b. Collect auxiliary information when appropriate, e.g. wildlife habitat value, soils, quantitative plant description, etc.

7. Return to IDIMS and edit cluster statistics and pool and/or delete cluster classes

8. Produce preliminary classification based on edited cluster statistics

9. Evaluate preliminary classification based on edited cluster statistics

10. Post-classification refinement where necessary to improve classification accuracy. This step may be facilitated by several approaches, two of which are presented:

    a. Stratification based upon physiognomic, soil or other resource data

       (1) Digitize boundaries of strata
       (2) Produce and apply strata mask
       (3) Identify cluster classes for each strata
       (4) Combine classifications for all strata
       (5) Reclassify entire study area

    b. Merge DEM digital terrain data with Landsat data

       (1) Define control points for DEM
       (2) Generate transformation between latitude/longitude (DEM) and UTM grid
       (3) Register DEM to UTM grid
       (4) Generate slope and aspect data
       (5) Define strata based on combinations of elevation, slope, and aspect
       (6) Identify cluster classes within each strata

11. Extract 1:250,000 USGS quadrangle coverage from each scene and mosaic data covering the same quadrangles together, repeat steps 10a and 10b where applicable

APPENDIX A

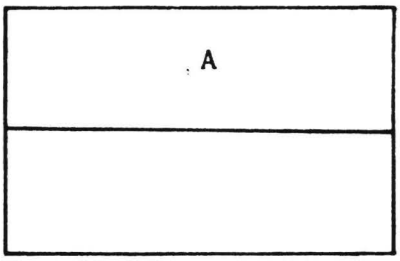
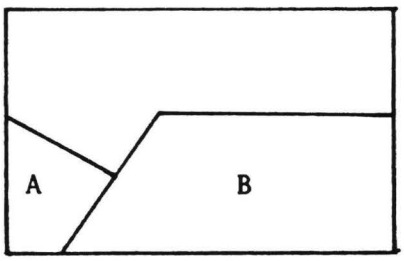
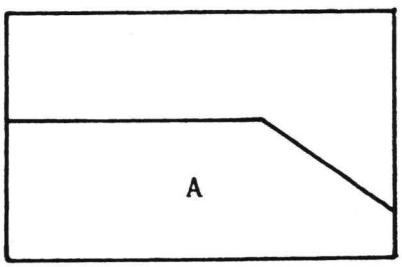
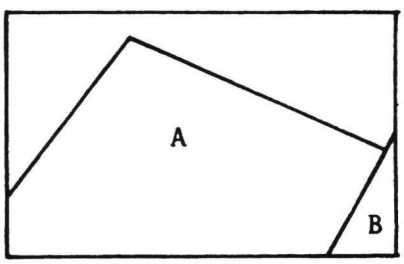
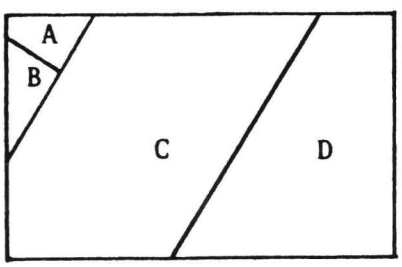
Generate Output Products

1. Generate digital tape file for classification of refuge or portions of refuge (1:250,000 USGS quadrangles)

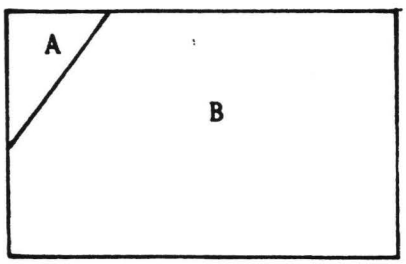
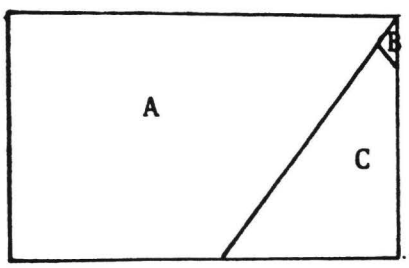
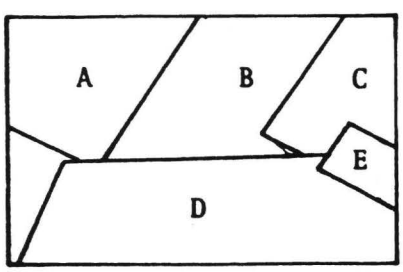
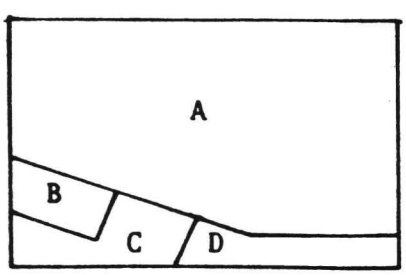
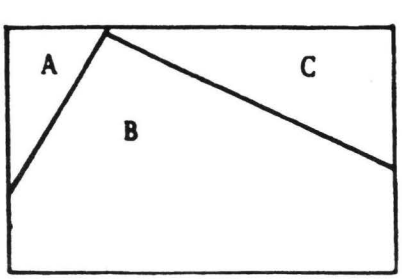
2. Produce acreage estimate for refuge or units (quadrangles) within refuge area

3. Produce Applicon ink jet plots for final classifications of the refuge area on a 1:250,000-scale USGS quadrangle

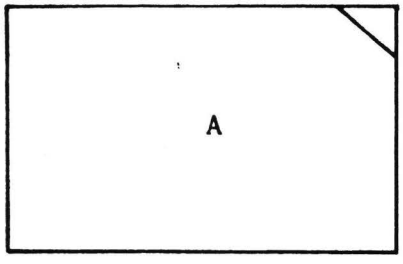
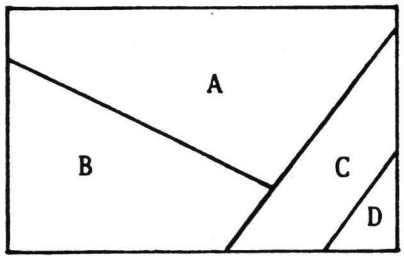
APPENDIX B

QUAD		SCENE ID	DATE
BLACK RIVER			
	A	2583-20181	27 August 1976
FLAXMAN ISLAND			
	A	21633-20531	13 July 1979
	B	21570-20462	14 August 1976
BARTER ISLAND			
	A	22386-20391	4 August 1981
SAGAVANIRKTOK			
	A	21634-20592	14 July 1979
	B	22387-20445	5 August 1981
MT. MICHELSON			
	A	21633-20531	13 July 1979
	B	2570-20462	14 August 1976
	C	22387-20445	5 August 1981
	D	22386-20391	4 August 1981

APPENDIX B

QUAD		SCENE ID	DATE
ARCTIC			
	A	22387-20445	5 August 1981
	B	22386-20391	4 August 1981
TABLE MTN.			
	A	22386-20391	4 August 1981
	B	2927-20135	6 August 1977
	C	2583-20174	27 August 1976
CHANDALAR			
	A	2570-20462	14 August 1976
	B	22387-20445	5 August 1981
	C	22386-20391	4 August 1981
	D	31636-20533	27 August 1982
	E	22387-20445	5 August 1981
CHRISTIAN			
	A	22386-20391	4 August 1981
	B	22387-20445	5 August 1981
	C	31636-20533	27 August 1982
	D	21305-20183	19 August 1978
COLEEN			
	A	22386-20391	4 August 1981
	B	2583-20181	27 August 1976
	C	2583-20174	27 August 1976

APPENDIX B

QUAD		SCENE ID	DATE
DEMARCATION POINT			
	A	22386-20391	4 August 1981
PHILIP SMITH MTNS.			
	A	21633-20531	13 July 1979
	B	2570-20462	14 August 1976
	C	22387-20445	5 August 1981
	D	22386-20391	4 August 1981

APPENDIX C

VEGETATION CLASSIFICATION FOR THE ARCTIC NATIONAL WILDLIFE REFUGE LAND COVER MAP

Forest

Forests are formed of tree species at least 5 meters tall. Included within the concept of forest is secondary tree growth temporarily less than 5 meters in height, i.e., intermediate succession stages. The major forest subclasses identified within the study area are: 1) closed needleleaf forest, 2) open needleleaf forest, 3) needleleaf woodland, 4) deciduous forest, and 5) mixed forest.

CLOSED NEEDLELEAF FOREST. -- Percentage cover of trees in this subclass ranges from 60 - 100%. It consists primarily of Picea glauca on moist to well drained sites and is only found south of the Continental Divide. Species commonly found in the understory include Rosa acicularis, Shepherdia canadensis, Salix sp, Pyrola sp, Betula glandulosa, Vaccinium uliginosum, V. vitis-idaea, Carex sp, Eriophorum sp and Hylocomium splendens. (Figure C.1)

OPEN NEEDLELEAF FOREST (30 - 60% tree cover). -- This subclass consists of open stands of trees with their crowns not usually touching. It is primarily dominated by Picea mariana on low, poorly drained sites or upland sites with permafrost. Included in the concept is Picea glauca on alluvial sites and on moist to well drained sites in the uplands and subalpine zone. (Figure C.2)

The shrub layer usually consists of Salix glauca and Alnus crispa on alluvial sites and on moist to well drained sites. The dwarf shrub layer is the more common type of understory occurring with this type and usually consists of Ledum decumbens or L. groenlandicum, Vaccinium uliginosum, Betula glandulosa, Empetrum nigrum, Eriophorum vaginatum. Cladonia sp and Cladina sp. Other species which may occur include Arctostaphylos rubra, A. arctica, Dryas integrifolia, Rhododendron sp, Salix reticulata, Salix lanata, Carex Bigelowii, Festuca altica, Equisetum arvensis and Hylocomium splendens.

NEEDLELEAF WOODLAND (5 - 30% tree cover). -- This subclass is dominated by a shrub layer but contains an important stratum containing Picea mariana or P. glauca (greater than 3 meters in height). Major shrub species include Betula nana, Ledum groenlandicum, L. decumbins, Vaccinium uliginosum, V. vitis-idaea, Salix reticulata, S. glauca, S. lanata, Alnus crispa, and Dryas integrifolia. Non woody species may include Lupinus arcticus, Equisetum arvense, E. scirpoides, Eriophorum vaginatum, Carex Bigelowii, C. scirpoides, Festuca sp., Cetraria sp., Cladina sp., Polytrichum sp., Hylocomium splendens, and Dicranium sp. (Figure C.3)

DECIDUOUS FOREST/TALL SHRUB (25 - 100% tree cover). -- Betula papyrifera, Populus tremuloides and P. balsamifera are the dominant species occurring in this class. Salix alexensis may also be classified in this class on alluvial terraces by itself or mixed with P. balsamifera. This class is normally found on well drained to moist soils associated with hills and alluvial terraces south of the continental divide. North of the divide this type is rare, occurring mainly along the Canning River. Also included are Alnus crispa and Salix sp, Rosa acicularis, Shepherdia canadensis, and Calamagrostis canadensis. (Figure C.4)

MIXED FOREST (25 - 100% tree cover) is formed by deciduous broadleaf and evergreen needleleaf trees and occurs on well drained to moist sites in the uplands. The primary needleleaf species is Picea glauca, while the major broadleaf species is Betula papyrifera and occasionally Populus balsamifera and P. tremuloides. Some alluvial sites are represented by tall Salix species that exceed 5 meters. The 'Mixed Forest' subclass is not abundant and is restricted to the south side of the Brooks Range below an elevation of 500 meters. Understory species common to the needleleaf classes and the deciduous class may also be found in this class along with Ribes sp, Lupinus articus and Juniperous communis on drier sites. (Figure C.5)

Scrub

This vegetation class is predominantly composed of shrubs (greater than 25% cover) 0.5 to 5 meters in height that shed their foliage simultaneously in connection with the unfavorable season.

ALLUVIAL DECIDUOUS SCRUB occurs on frequently flooded gravel sites dominated by Salix planfolia ssp. pulchra and S. alaxensis. On some sites especially on the coastal plain, Betula species (dwarf birch) may occur with Salix in older alluvial terraces. The number of species occurring with the above species as co-dominents or as understory are many and may include Salix lanata, S. richardsonii, S. glauca, S. brachycarpa, S. hastata, S. reticulata, Arctostaphylos rubra, Populus balsamifera, Shepherdia canadensis, Potentila polustris, Dryas integrifolia, D. drummondii, Equisetum arvensi, E. varigatum, E. scirpoides, Carex sp, Festuca sp, Juncus casteneus, Petasites sp, Hedyserum sp and Hylocomium sp. (Figure C.6)

This class is not distinguished on the coastal plain but included in the scarcely vegetated floodplain type. Species composition and density is usually controlled by frequency of flooding and water velocity and particle load during flooding.

DRY PROSTRATE DWARF SCRUB. -- This formation occupies slightly elevated microsites on the coastal plain, upper slope positions in the foothills and mountains, and may occur on dry alluvial terraces or fans above 300 meters in the mountains. Bare soil is often an important component of the ground surface as a result of frost action. Because of the harsh environment, plants do not achieve heights greater than 10 cm. Some of the more commonly occurring shrubs are Dryas integrifolia (usually dominant) and D. octopetala with Arctostaphylos rubra, Salix reticulata, S. oppositifolia, S. rotundifolia and Cassiopia tetragona, Non-woody species include Saxifraga hircula, Polygonum bistort, Petasites arctica, Polemonium sp, Equisetum arvensis, Carex sp, Festuca sp, Hierochloi sp, Epilobium latifolium, Geum glaciale and the lichen Cetraria sp. (Figure C.7)

Comparable types of Walker et al. (1982) include: 'IVb. Dry Prostrate Scrub, Forb Tundra' and 'Vb. Moist Sedge/Barren Tundra Complex' (in part).

MOIST PROSTRATE DWARF SCRUB. -- This type contains prostrate dwarf shrub and sedge formations occupying mesic habitats on gentle to moderately steep slopes. In the foothills, these habitats are frequent on mid to lower slopes which receive subsurface drainage from adjacent terrain. Dryas integrifolia is often the dominant species. Equistem arvense and the moss, Tomenthypnum nitens are characteristic species of this formation. Carex Bigelowii gives the habitat a hummocky surface. Moist habitats on slightly elevated microsites in the coastal plain, and alluvial terraces in the foothills and mountains are often drier as a result of greater exposure and lack of water from surrounding terrain. Lichens are more important than mosses in these drier habitats. These habitats are very similar to the moist microsites of the wet/moist dwarf shrub, graminoid land cover class. (Figure C.8)

Other species important to this type include Salix arctica, S. lanata, S. pulchra, Rubus chamaemorus, Saxifraga hirculus, S. punctata, Petasites frigidus, Eriophorum vaginatum and Carex aquatilis.

Corresponds to the following Walker et al. (1982) categories: 'Va. Moist Sedge, Prostrate Shrub Tundra', VIb. Moist Sedge Tussock, Dwarf Shrub Tundra (upland tussock tundra, aklaline facies)', and VIIb. Moist Dwarf Shrub, Sedge Tussock Tundra (birch tundra)'.

MESIC ERECT DWARF SCRUB (INCLUDES THE CONCEPT OF DWARF SCRUB GRAMINOID TUSSOCK). -- This subclass is comprised of erect dwarf shrubs, primarily from the taxa Betula sp, Salix sp, Vaccinium uliginosum and Cassiope tetragona. These shrubs are usually 0.1 m to 0.5 m in height with interlocking branches. This type is common on lower mountain slopes, low rolling hills, and old burns. On mountain bases with low slope values (0 - 15% slope) or on hill sides at lower elevations (below 900 m), graminoid tussocks often occur with the dwarf shrub. Major tussock producing plants include Eriophorum Vaginatum and Carex bigelowii. Major shrub species include Betula glandulosa, B. nana, Salix glauca, S. reticulata, S. planifolia ssp. pulchra, Ledum decumbens, Vaccinium vitis-idaea, and Empetrum nigrens. Other species present may include Carex lugens, Carex scirpoidea, Equisetum arvensis, E. scirpoidea, Hylocomium splendens, Tomenthypnum nitens and Sphagnum sp. (Figure C.9)

Corresponding classes from Walker et al. (1982) are: 'VIIa. Moist Dwarf Shrub, Sedge Tussock Tundra (upland dwarf shrub, tussock tundra), and 'VIIc. Moist Sedge Tussock, Dwarf Shrub/Wet Dwarf Shrub Tundra Complex (water track complex)'.

Herbaceous

Herbaceous plants are without significant woody tissue and die back to the ground surface each year. There are two major growth forms: graminoids and forbs. Graminoids include all non-woody grasses and grasslike plants such as Carex (sedges) and Eriophorum (cottongrass). Forbs are broad-leaved herbaceous plants such as Petasites (coltsfoot) and Epilobium (fireweed). Four subclasses are recognized: 1) 'very wet graminoid', 2) 'wet graminoid', 3) 'wet/moist dwarf shrub graminoid' and 4) 'moist graminoid tussock - scrub'.

VERY WET GRAMINOID. -- A graminoid dominated formation associated with aquatic habitats surrounding large, open bodies of fresh water, very wet habitats which contain numerous small bodies of open water and coastal habitats frequently inundated with salt water. Surface forms include low center polygons with abundant standing water, thaw lake basins, the littoral zones of lakes and the coastline. Arctophila fulva is the primary species in deeper water, up to 1 m deep, with Carex aquatilis, Eriophorum scheuchzeri and Eriophorum angustifolium dominating areas where the water is less tha 30 cm deep. (Figure C.10)

Corresponding classes of Walker et al. (1982) are: 'IIIb. Wet Sedge Tundra (very wet complexes)' and 'IIId. Wet Sedge Tundra (saline facies)'; Bergman et al. (1977) classes: 'II. Shallow Carex' and 'V. Basin Complex'.

WET GRAMINOID. -- Graminoid formations associated with wet habitats. These habitats often receive water by surface and subsurface flow from surrounding terrain. The habitats generally have standing water throughout the summer. Vegetation coverage is continuous, as depth of water is not a limiting factor to plant establishment and growth. The habitat has few drained microsites associated with polygon rims, strangmoor, hummocks, etc. Landforms where these habitats occur are river deltas, drained lake basins, and river channels, where surface forms are low centered polygons, and strangmoor. Primary taxa include numerous Carex spp., Eriophorum spp. Common species occurring in this type include Carex aquatilis, C. microglochin, C. atrofusca, C. amblyorhyncha, C scirpoidea, C. rustrata, C. bigelowii, C. physocarpa, C. misandra, Eriophorum vaginatum, E. angustifolium, E. russeolum, Equistum fluviatile, Scurpus scurpoides, S. caespitosus, Pedicularis sp, Valeriana capitata, Polygonum sp, Tomenthypnum nitens and Drapanocladus sp. Some scrub species include Arctostaphylos rubra, Salix lanata, and S. arctophila. (Figure C.11)

Corresponding classes of Walker et al. (1982) are 'IIIa. Wet Sedge Tundra (noncomplex)' but excludes 'IIIb. Wet Sedge Tundra (very wet complexes)', 'IIIc. Wet Sedge Tundra (moist complexes)', and 'IIId. Wet Sedge Tundra (saline facies)'; Bergman et al. (1977): 'I. Flooded Tundra'. This subclass may also be similar to that reported by Hettiger and Janz (1974) 'I. Wet Sedge Meadows'.

MOIST/WET TUNDRA COMPLEX -- In this type, dwarf shrubs and graminoids occur together in habitats intermediate in moisture regime between the wet graminoid and moist dwarf shrub formations. High-center and flat-center polygons are common surface features in river delta and drained lake basin landforms. Along river drainages, disjunct string bogs are the most common land surface form. Wet and moist microsites are often intermixed in a complex pattern in this habitat. Common species on these sites include Dryas integrifelia, Salix lanata, S. reticulata, Cassiope tetragona, Vaccinium uliginosum, Eriophorum triste, E. vaginatum, Carex bigelowii, C. membranacea, Polygonum bistorta, stellaria laeta, Senecio sp, Tomenthypnum nitens and Hylocomium sp. (Figure C.12)

Comparable Walker et al. (1982) types are: 'IVa. Moist/Wet Sedge Tundra Complex' and 'IIIc. Wet Sedge Tundra (moist complexes)' but excludes 'IVb. Dry Prostrate Shrub, Forb Tundra'.

MOIST GRAMINOID TUSSOCK. -- This subclass is related to part of the shrub subclass 'mesic erect dwarf scrub'. This type differs from the later class in that it is dominated by the graminoid component. In essence, the recognition of these two subclasses acknowledges the physiognomic continuium and attempts to distinguish subclasses based on the relative abundance of dwarf shrubs and the graminoid tussocks. Physiognomic characteristics of this class are similar to those described in the subclass containing dwarf scrub graminoid tussocks. Species dominating this class include the tussock producing Eriophorum vaginatum and Carex bigelowii. Also occurring are Betula nana, Salix planafolia subsp pulchra, S. reticulata, Dryas integrifolia, Vaccinium uliginosum V. vitis-idaea, Pyrola sp, Polygonum bistort, P. viviparum, Cetraria sp, Tomenthypnum nitens, Hylocomium splendens, and Ptilidium ciliare. (Figure C.13)

The corresponding type from Walker et al. (1982) is 'VIa. Moist Sedge Tussock, Dwarf Shrub Tundra (upland tussock tundra, acid facies)'.

Scarcely Vegetated Areas

In this class plants are scattered or absent and bare mineral soil or rock determines the overall appearance of the landscape.

SCARCELY VEGETATED SCREE (5 - 20% plant cover) is comprised of more or less unstable steep slopes of stones beneath weathering rocks. It is a very open fellfield and often grades into 'dry prostrate dwarf scrub'. Some shrubs commonly found in this type in prostrate or decumbent forms include Betula nana, Dryas integrifolia, D. octopetala, Vaccinium uliginosum, Cassiope tetragona, Salix phlebophila. Some other species found include Umbilcana sp, Crystopteris sp, Diapensia lapponica, Cetraria sp, Lupinus arcticus, and Carex Sp. (Figure C.14)

BARREN SCREE (less that 5% plant cover) is less vegetated than scarcely vegetated scree. A type of lichen tundra may form dominated by blackish lichens, particularly the genera Umbilicaria, Cetraria, Cornicularia, and Pseudophebe. These plants are on the very limit of life's possibilities. The sites may be devoid of flowering plants. (Figure C.15)

SCARCELY VEGETATED FLOODPLAIN. -- This subclass is a result of the initial invasion of plants on recent river alluvium. Plant cover averages 5 - 20%. Some of the more common species include Epilobium latifolium, Calamagrostis canadensis, Bromus sp and Salix sp. On the coastal plain (below the 500 meter contour) this type includes alluvial deciduous scrub communities. (Figure C.16)

BARREN FLOODPLAIN is less vegetated than 'scarcely vegetated floodplain'. It consists of alluvium and includes silt, sand and rocks. Plant cover is less than 5% and include the same species as 'scarcely vegetated floodplain' if present. (Figure C.17)

Other

CLEAR WATER. -- Clear water including lakes, ponds, and rivers. (Figure C.18)

SHALLOW WATER. -- This type includes riverine areas in which the water is shallow or when the satellite sensor received spectral data from both water and gravel bars and recorded them as one class.

OFFSHORE WATER. -- The Beaufort Sea shoreline was digitized on the Flaxman Island, Barter Island, Demarcation Point and Mt. Michelson quads and applied to the land cover image. Those water areas north of the shoreline were labeled offshore water. (Figure C.19)

CLOUDS - SNOW - ICE. -- This type is highly variable and is dependent upon individual yearly weather patterns. Ice, in the form of pack ice and aufeis may or may not be present on the ground or in the ocean as depicted on the map. Glacial ice in the mountains is probably stable and what is shown on the map could be found on the ground. This may not be true of the Philip Smith Mountains quad however, as a later acquired scene was used which contained an early snow fall. (Figure C.20)

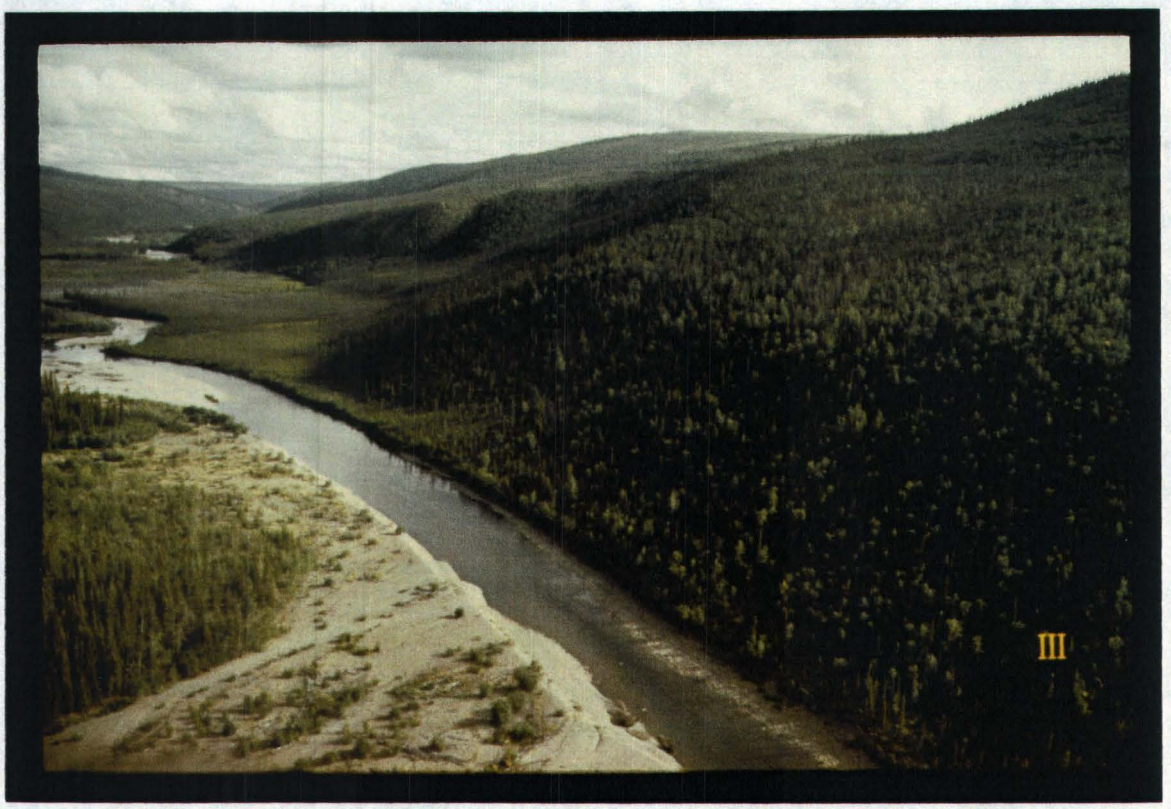
SHADOW. -- This type includes both terrain shadow (i.e. mountain shadow) and cloud shadow.

ROADS/PIPELINE -- The North Slope Haul Road and Trans-Alaska Pipeline were digitized and added to the Sagavanirktok and Philip Smith Mountains quads. (Figure C.21)

C.1

C.2

C.3



C.4

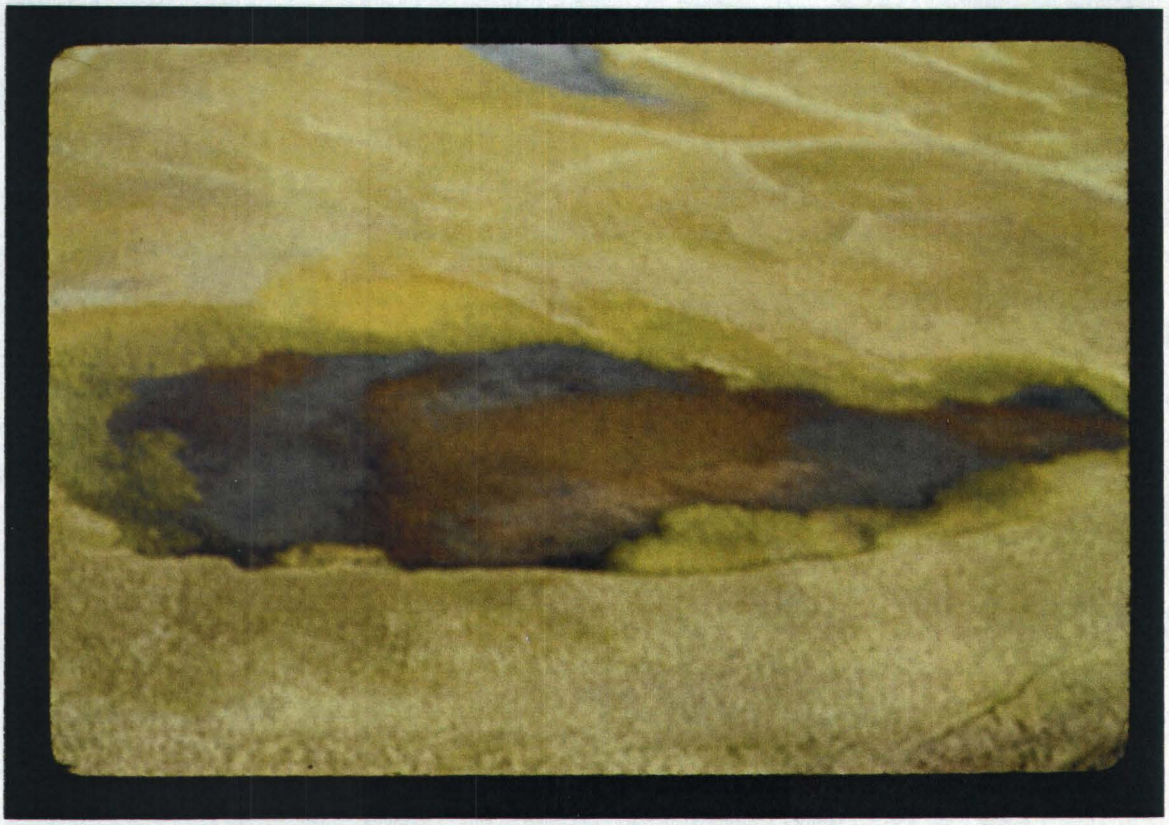
C.5

C.6

C.7

C.8

C.9



C.10

C.11

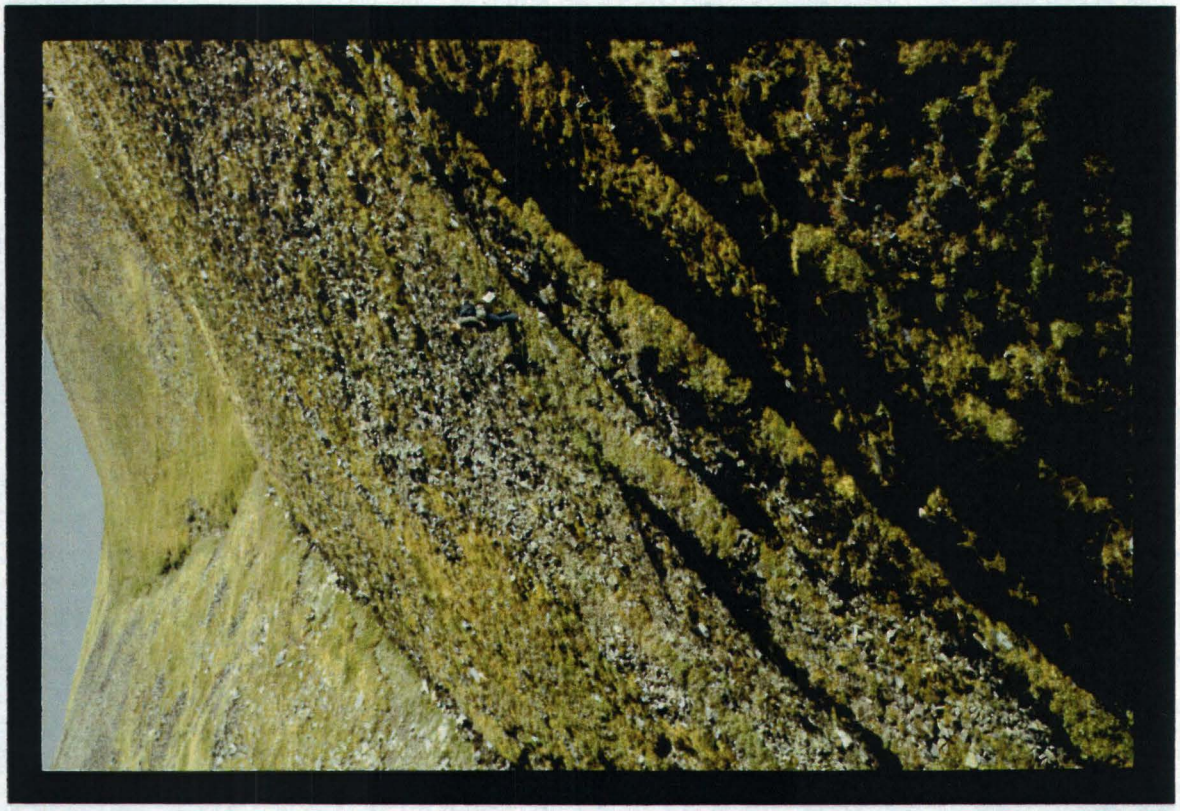
C.12

C.13

C.14

C.15

C.16



C.17

C.18

C.19

C.20

C.21

APPENDIX D

IMAGE AREA	TYPE OF IMAGE (1)	NUMBER OF LINES	NUMBER OF SAMPLES	NORTHING (M)	EASTING (M)	PIXEL SIZE	DATA TYPE
FLAXMAN ISL.	LCC	2550	2500	7886550	497000	50	BYTE
BARTER ISL.	LCC	2700	2400	7889550	385500	50	BYTE
SAGAVANIRKTOK	LCC	2700	2500	7778150	379650	50	BYTE
MT. MICHELSON	LCC	2550	2650	7775000	496850	50	BYTE
PHILIP SMITH MTN.	LCC	2700	2800	7666750	373900	50	BYTE
DEMARCATION PT.	LCC	2700	2500	7778150	379650	50	BYTE
ARCTIC	LCC	2550	2750	7663500	496700	50	BYTE
TABLE MTN.	LCC	2700	2600	7666750	373900	50	BYTE
CHANDALAR	LCC	2700	2750	7555400	368150	50	BYTE
CHRISTIAN	LCC	2550	2850	7552000	496550	50	BYTE
COLEEN	LCC	2700	2750	7555400	368150	50	BYTE
BLACK RIVER	LCC	2700	2850	7444000	362450	50	BYTE

(1) LAND COVER CLASSIFICATION

IMAGE AREA	TYPE OF IMAGE	NUMBER OF LINES	NUMBER OF SAMPLES	NORTHING (M)	EASTING (M)	PIXEL SIZE	DATA TYPE
FLAXMAN ISL.	ASPECT	2550	2500	7886550	497000	50	BYTE
BARTER ISL.	ASPECT	2700	2400	7889550	385500	50	BYTE
SAGAVANIRKTOK	ASPECT	2700	2500	7778150	379650	50	BYTE
MT. MICHELSON	ASPECT	2550	2650	7775000	496850	50	BYTE
PHILIP SMITH MTN.	*	2700	2800	7666750	373900	50	BYTE
DEMARCATION PT.	ASPECT	2700	2500	7778150	379650	50	BYTE
ARCTIC	ASPECT	2550	2750	7663500	496700	50	BYTE
TABLE MTN.	ASPECT	2700	2600	7666750	373900	50	BYTE
CHANDALAR	ASPECT	2700	2750	7555400	368150	50	BYTE
CHRISTIAN	ASPECT	2550	2850	7552000	496550	50	BYTE
COLEEN	ASPECT	2700	2750	7555400	368150	50	BYTE
BLACK RIVER	ASPECT	2700	2850	7444000	362450	50	BYTE

*DATA NOT AVAILABLE

APPENDIX D

IMAGE AREA	TYPE OF IMAGE	NUMBER OF LINES	NUMBER OF SAMPLES	NORTHING (M)	EASTING (M)	PIXEL SIZE	DATA TYPE
FLAXMAN ISL.	ELEVATION	2550	2500	7886550	497000	50	INTEGER
BARTER ISL.	ELEVATION	2700	2400	7889550	385500	50	INTEGER
SAGAVANIRKTOK	ELEVATION	2700	2500	7778150	379650	50	INTEGER
MT. MICHELSON	ELEVATION	2550	2650	7775000	496850	50	INTEGER
PHILIP SMITH MTN.	*	2700	2800	7666750	373900	50	INTEGER
DEMARCATION PT.	ELEVATION	2700	2500	7778150	379650	50	INTEGER
ARCTIC	ELEVATION	2550	2750	7663500	496700	50	INTEGER
TABLE MTN.	ELEVATION	2700	2600	7666750	373900	50	INTEGER
CHANDALAR	ELEVATION	2700	2750	7555400	368150	50	INTEGER
CHRISTIAN	ELEVATION	2550	2850	7552000	496550	50	INTEGER
COLEEN	ELEVATION	2700	2750	7555400	368150	50	INTEGER
BLACK RIVER	ELEVATION	2700	2850	7444000	362450	50	INTEGER

*DATA NOT AVAILABLE

IMAGE AREA	TYPE OF IMAGE	NUMBER OF LINES	NUMBER OF SAMPLES	NORTHING (M)	EASTING (M)	PIXEL SIZE	DATA TYPE
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BARTER ISL.	SLOPE	2700	2400	7889550	385500	50	BYTE
SAGAVANIRKTOK	SLOPE	2700	2500	7778150	379650	50	BYTE
MT. MICHELSON	SLOPE	2550	2650	7775000	496850	50	BYTE
PHILIP SMITH MTN.	*	2700	2800	7666750	373900	50	BYTE
DEMARCATION PT.	SLOPE	2700	2500	7778150	379650	50	BYTE
ARCTIC	SLOPE	2550	2750	7663500	496700	50	BYTE
TABLE MTN.	SLOPE	2700	2600	7666750	373900	50	BYTE
CHANDALAR	SLOPE	2700	2750	7555400	368150	50	BYTE
CHRISTIAN	SLOPE	2550	2850	7552000	496550	50	BYTE
COLEEN	SLOPE	2700	2750	7555400	368150	50	BYTE
BLACK RIVER	SLOPE	2700	2850	7444000	362450	50	BYTE

*DATA NOT AVAILABLE

APPENDIX D

IMAGE AREA	TYPE OF IMAGE	NUMBER OF LINES	NUMBER OF SAMPLES	NORTHING (M)	EASTING (M)	PIXEL SIZE	DATA TYPE
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ENTIRE STUDY AREA	ELEVATION	2200	2000	7795000	369150	200	INTEGER
ENTIRE STUDY AREA	ASPECT	2200	2000	7795000	369150	200	BYTE
ENTIRE STUDY AREA	SLOPE	2200	2000	7795000	369150	200	BYTE

(1) LAND COVER CLASSIFCATION