Development of a Digital Land Cover Data Base for the Selawik National Wildlife Refuge

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DEVELOPMENT OF A DIGITAL LAND COVER DATA BASE FOR THE SELAWIK NATIONAL WILDLIFE REFUGE

By Carl Markon[1] and William Kirk[2]

ABSTRACT

Digital land cover and terrain data of the Selawik National Wildlife Refuge were produced by the U.S. Geological Survey's (USGS) Earth Resources Observation Systems Alaska Field Office for the U.S. Fish and Wildlife Service. These and other environmental data were incorporated into a Fish and Wildlife Service geographic information system to prepare a comprehensive conservation plan and an environmental impact statement for the refuge and to assist in research and management of the refuge.

The digital data base, stored on tapes, includes land cover classifications from Landsat multispectral scanner data, elevation, slope, and aspect data for the area covered by the USGS Selawik and Shungnak 1:250,000-scale topographic maps. The maps incorporate more than 90 percent of the refuge. Additional digital data in the data base include (a) land cover of the entire refuge at 50-, 200-, and 400-m pixel sizes derived from Landsat multispectral scanner data; (b) Landsat multispectral scanner data registered to a 50-m Universal Transverse Mercator grid; (c) elevation, slope, aspect, and solar illumination data registered to each Landsat scene; (d) stream hydrography and surficial geology digitized from USGS 1:250,000-scale quadrangle maps; and (e) Refuge and wilderness boundaries.

In addition to the digital products, color hard copy maps were produced from the 1:250,000-scale quadrangle base land cover, elevation, slope, and aspect digital data.

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INTRODUCTION

The Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96-487) was enacted in 1980 to provide and conserve certain public lands in Alaska. The Act instructs the U.S. Fish and Wildlife Service (USFWS) to identify and describe the habitats of the fish and wildlife resources on the Selawik National Wildlife Refuge (SNWR). Because vegetation forms the basis of habitat (Egler, 1977) and topography affects the vegetative composition and use of habitat, a digital data base containing land cover and terrain data such as elevation, slope, and aspect was needed. The USFWS and the U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center entered into a cooperative project to develop this data base which was used to prepare a comprehensive conservation plan and an environmental impact statement for the Refuge. These data are also being used in research and management on the Refuge.

Published vegetation maps of the refuge are limited. Broad or regional land cover classifications were produced by Kuchler (1966) at a scale of 1:7,500,000, and Selkregg (1975) at a scale of 1:1,500,000. Becia (1987) produced 1:60,000-scale maps that covered a few western portions of the refuge. A computer- assisted analysis of Landsat multispectral scanner (MSS) data was used because (1) high-altitude aerial photography for the refuge was limited; (2) complete satellite coverage of the refuge could be obtained; (3) the level of detail would be adequate to meet most of USFWS planning, research, and management needs; and (4) the data base could be registered to other data bases and quickly retrieved. This paper describes the methodology used to produce the land cover classification and accompanying data base, as well as the different types of products developed.

STUDY AREA

The SNWR encompasses approximately 3.2 million acres of land and water in northwestern Alaska (fig. 1). The study area covers roughly 1 degree of latitude and 6 degrees of longitude.

Figure 1.--Near here.

The refuge is contained in the western Alaska Province, Intermontane Plateau, physiographic division as described by Wahrhaftig (1965). The refuge is bordered on the north by the Kobuk River and Waring Mountains, and by Hotham Inlet and Selawik Lake on the west. To the south are the Selawik Hills extending eastward to the Purcell Mountains. The Selawik River, which flows westward into Selawik Lake, bisects the refuge.

The refuge consists mainly of broad river floodplains such as the Kobuk River delta in the northwest, and lake-dotted lowlands. Most of the refuge is underlain by glacial moraine deposits and by stream and lake deposits. To the north, the Waring Hills are underlain by Cretaceous sedimentary rocks (Wahrhaftig, 1965). Large, inactive and small, active sand dunes are prominent in the north central portion of the refuge. Permafrost throughout the refuge causes patterned ground and occasional pingos.

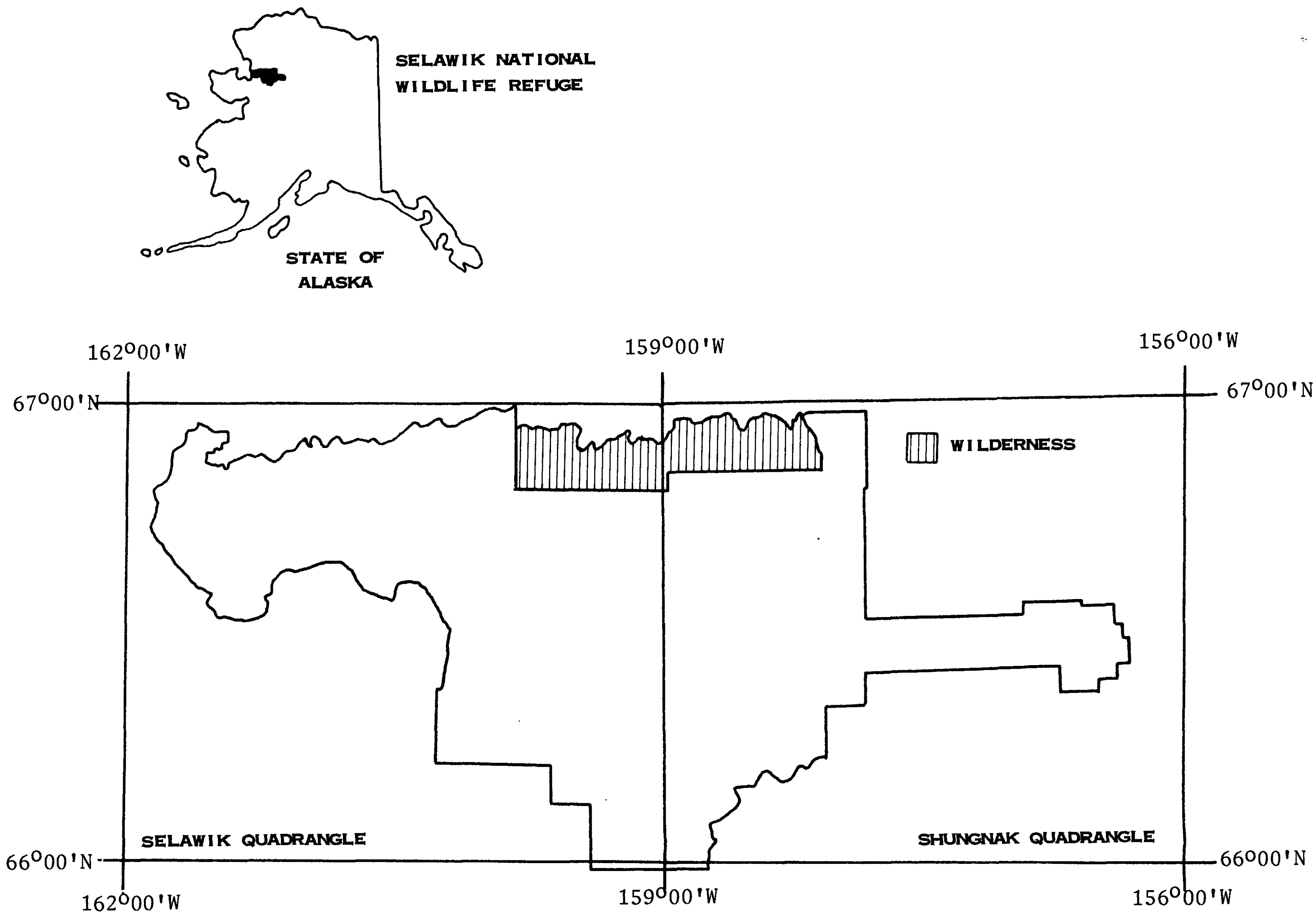

Figure 1.--Location of Selawik National Wildlife Refuge and 1:250,000-scale U.S. Geological Survey topographic quadrangles.

General vegetation identified by the Alaska Regional Profiles - Northwest Region (Selkregg, 1975) include: moist tundra, alpine tundra and barren ground, wet tundra, upland spruce - hardwood forest, high brush, bottomland spruce - poplar forest, lowland spruce - hardwood forest, and low brush bog and muskeg.

METHODOLOGY

Data Base Design

The boundaries of the SNWR extend into five 1:250,000-scale topographic maps. Two of the maps, Selawik and Shungnak, form the basic units in which the data base was organized, each unit being georeferenced to different Universal Transverse Mercator (UTM) origins in zone 4. Minimum data resolution was 50 m by 50 m for each picture element, or pixel. Data were stored on computer compatible tape (CCT) enabling transfer to the USFWS geographic information system. A schematic diagram of the mapping and data base development process is shown in figure 2.

Figure 2.--Near here.

Data Acquisition

Three Landsat MSS scenes (table 1) were required to provide complete coverage of the SNWR and surrounding lands (fig. 3).

Table 1.--Near here.

Eleven training blocks, sample areas containing representative landcover types, were selected for field study (fig. 3).

Figure 3.--Near here.

Blocks representing the spectral and floristic variation within each scene were selected based on visual interpretation of the Landsat scenes. Color-infrared aerial photographs (approximate scale 1:60,000) were obtained for each training block and used to select 15 to 20 homogeneous polygons representing the vegetation. These polygons were then visited in the field using helicopter and ground surveys. An aerial pass was made of the site to collect information on community structure and physiognomy and to obtain low-altitude oblique 35-mm photographs. A ground survey determined vegetation cover, structure, and composition information using procedures described in Talbot and Markon (1988).

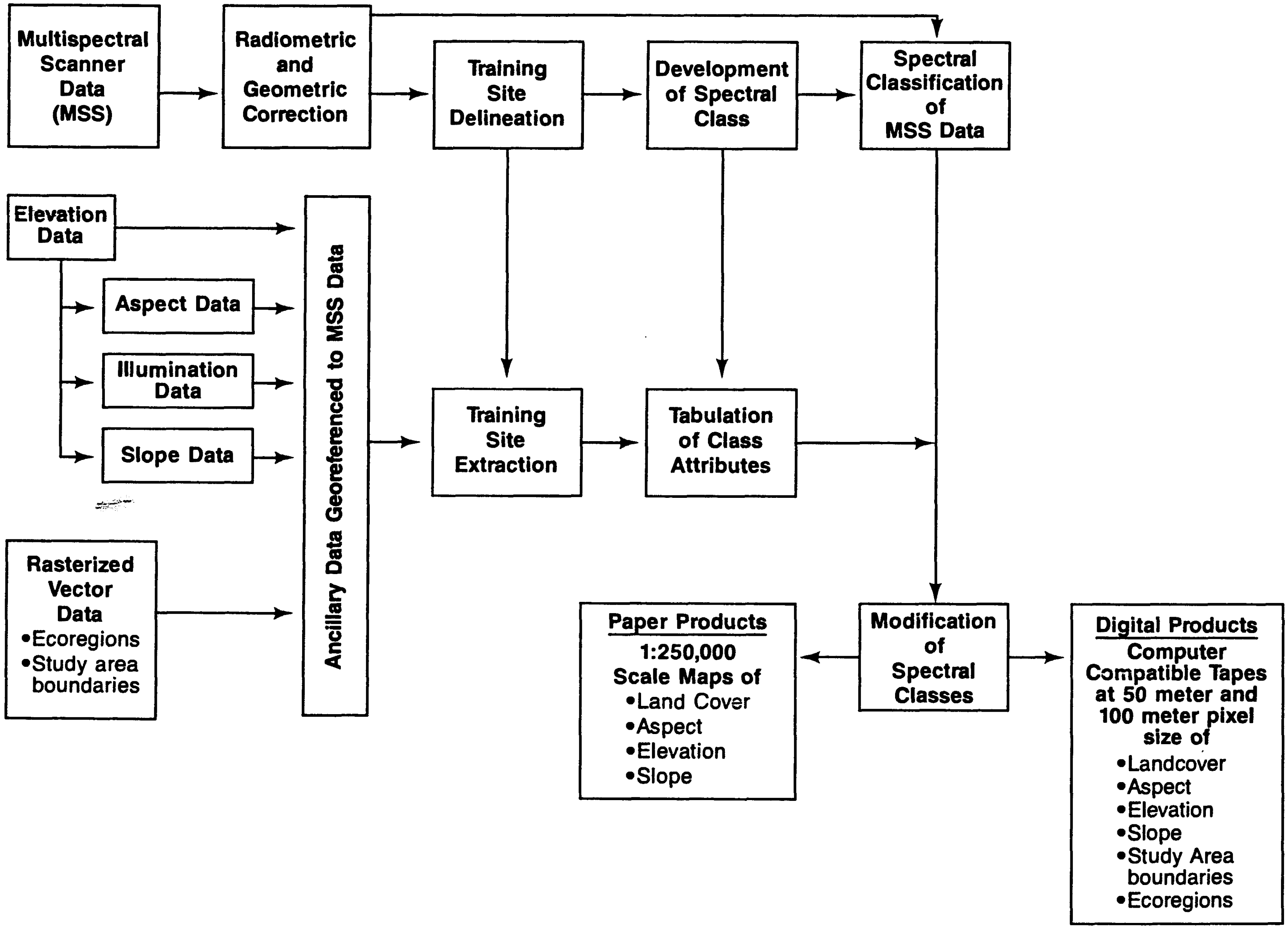

Figure 2.--Schematic diagram of the mapping process used to produce the land cover classification of the Selawik National Wildlife Refuge.

Table 1.--List of Landsat multispectral scanner scenes acquired to cover the Selawik National Wildlife Refuge, along with the registration criteria

Path/row	Scene Identification number	Acquisition date	Number lines	Number samples	Northing	Easting
87/13	21297-21155	August 11, 1978	3000	2800	7,460,000	350,000
85/13	21691-21184	September 9, 1979	3600	4050	7,460,000	365,000
83/13	30494-21462	July 12, 1979	3800	2600	7,460,000	530,000

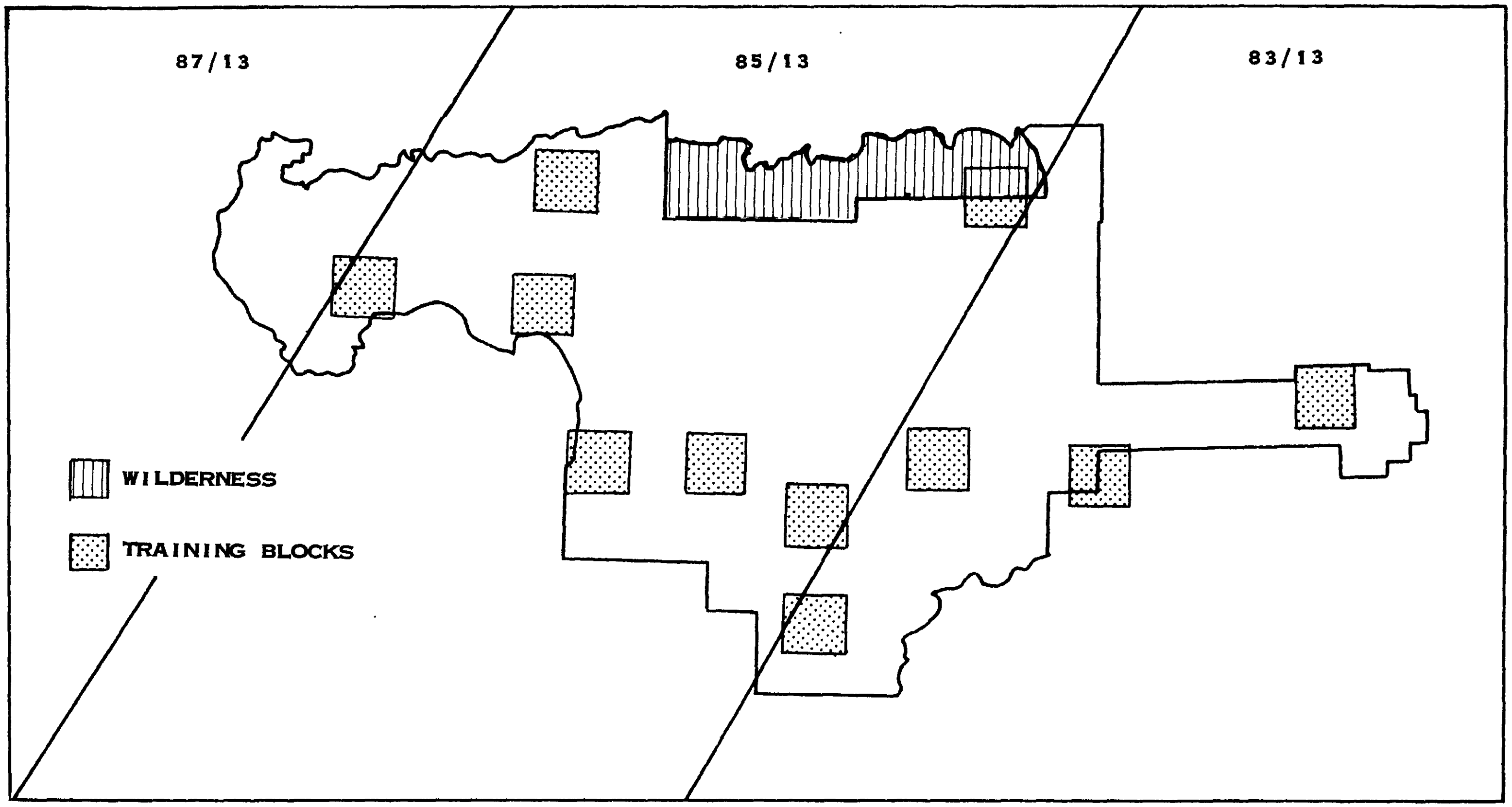

Figure 3.--Location of Landsat scenes and training blocks for the Selawik National Wildlife Refuge mapping project.

Using field data, an Earth Resources Information System (ERIS), produced an automated spreadsheet file on the USGS EROS Alaska Field Office interactive digital image manipulation system (IDIMS, ESL, Inc., 1981). This spreadsheet allowed 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 Landsat classification data, elevation (in meters), slope (in percent), aspect (in degrees), solar illumination, and winter Landsat MSS data. This spreadsheet enabled inferences on how to reduce confusion between spectral classes using stratification.

PREPROCESSING

Each Landsat scene was acquired in CCT (9-track) format and reviewed on the USGS EROS image processing system. This procedure ensured adequate coverage and documented the presence of clouds or bad data. Control points were selected from each Landsat scene, located on USGS 1:63,360-scale topographic maps, and used to define a second-order least squares polynomial transformation relating UTM zone 4 coordinates to the line and sample of each scene. 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 within 0.5 pixels (25m x 25m). Final registered scene dimensions and UTM coordinates are shown in table 1.

In addition to the Landsat MSS data, ancillary digital data such as refuge boundaries, USGS 1:250,000-scale quadrangle boundaries, stream hydrography, and surficial geology were acquired. These data were digitized from USGS 1:250,000-scale quadrangles, converted into image masks, and used during the land cover classification.

Digital elevation data for each 1:250,000-scale quadrangle from the Defense Mapping Agency (DMA) were georeferenced to the data base. The DMA generated the data by digitizing 200-foot contour lines from USGS 1:250,000-scale topographic maps and converting them to rectangular grid values.

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 was based on the Sun's elevation and azimuth at the time each Landsat scene was acquired. The computed illumination data resulted in values from 0 to 255, indicating the relative amount of light reflected from the ground surface. For example, low values would indicate shadows and high values would indicate sunny slopes.

Finally, winter Landsat MSS data were georeferenced to the data base. Winter Landsat MSS data have proven to be efficient in separating vegetation types because of the influence snow has on the spectral response for each land cover type (Fleming, 1988).

DEVELOPMENT OF SPECTRAL STATISTICS

Training statistics used to generate the preliminary classification were derived using a modified cluster-block technique (Fleming, 1975) for the 11 training blocks visited during the field study. The blocks were extracted from each scene and grouped in sets of two or four, depending on the scene each block represented.

The clustering function, ISOCLS (ESL, Inc., 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. Each cluster was defined in terms of descriptive statistics (means, standard deviations, covariance matrices between bands) for all bands. Redundant or overlapping statistics were removed or combined to form one statistical data set that provided an independent estimate of the spectral characteristics of each scene being analyzed.

CLASSIFICATION AND SPECTRAL CLASS LABELING

Final 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 pixel in the Landsat scene. The pixel brightness value was compared to the descriptive statistic values obtained for each cluster. Each pixel was assigned to one of the spectral clusters developed, based on the probability that the pixel belonged to the spectral class. The result was a classification where each pixel fell into a spectral class that represented a land cover class.

The spectrally classified training blocks were evaluated and each class was assigned a vegetation or land cover class 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 after classification. Frequently, spectral classes contained more than one vegetation type due to similar spectral response from (1) similar vegetation types, (2) the effects of shadow and water on the overall reflectance of the vegetation, and (3) variation of the vegetation due to elevation, slope, or aspect changes. One can determine if the classification is acceptable by reviewing the spectral clusters on the training blocks before scene classification. If it is not acceptable, ISOCLS would be performed again with different parameters on the training block set.

Following the identification of each spectral class in the training blocks, the statistical files were applied to the entire Landsat scene using the maximum likelihood 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 AND QUADRANGLE EXTRACTION

Preliminary classification accuracies are often low, due to similar spectral responses of different land cover types, variable terrain, and moisture presence. To increase the accuracy of the classification, ancillary data were applied to separate classes that were known to be 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, (3) winter data were used to separate shrubland from forested areas, and (4) surficial geology was used to separate those types associated only with sand dunes from the rest of the refuge.

Following the post classification phase, land cover and terrain data from each scene centered over the Selawik and Shungnak quadrangles were extracted (where applicable) and mosaicked. Further classification enhancement was applied by area as needed.

Accuracy Assessment

Insufficient funding precluded an accuracy assessment of the final map. Any comments regarding the usefulness of the product is based on personal observations and comments from coworkers and are strictly qualitative.

RESULTS

Land Cover Classification

The land cover classification for the Selawik National Wildlife Refuge resulted in seven major classes: barren, forest, herbaceous, shrub, dwarf scrub, water, and other. Within these classes are subclasses (table 2). The most prominent class identified on the refuge was dwarf scrub graminoid tussock (25.06 percent), followed by erect dwarf scrub/dwarf scrub lichen (21 percent), clear

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Table 2.--Near here.

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water (12.38 percent), and low shrub (10.56 percent). Table 2 gives acreage estimates for the entire refuge, including wilderness. A description of each land cover class is located in Appendix A.

Digital Products

Final digital products for the SNWR data base include land cover, elevation, slope, aspect, stream hydrography, and refuge boundary mask based on the 1:250,000-scale USGS quadrangles. These final data sets were stored on CCT's at 50-, 200-, and 400-m pixel sizes, as were the original and ancillary data used during the classification and post-classification processes.

Hard-Copy Map Products

Color hard-copy maps of the land cover, elevation, slope, and aspect were produced for the Selawik and Shungnak units at a 1:250,000 scale (Appendix B). Land cover classes shown are the same as the subclasses listed in table 2.

Table 2.--Acreage estimates of land cover occurring within the Selawik National Wildlife Refuge boundary.

Class number	Class	Acres refuge	Percent	Acres wilderness	Percent	Total acres	Percent of total
	Barren						
1	Scarcely vegetated flood plain	15149.09	0.51	1.85	.00	15150.95	0.47
2	Scarcely vegetated scree	10131.52	0.34	2153.92	0.89	12285.44	0.38
3	Dunes	1712.26	0.06	846.25	0.35	2558.51	0.08
	Forest						
5	Closed needleleaf	5179.41	0.17	1542.40	0.64	6721.81	0.21
6	Open needleleaf	136706.28	4.59	59749.50	24.71	196455.78	6.10
7	Needleleaf woodland	40607.60	1.36	21605.91	8.93	62213.51	1.93
8	Deciduous forest/tall shrub	92768.66	3.11	3763.65	1.56	96532.30	3.00
4	Open forested dunes	813.51	0.03	1630.11	0.67	2443.62	0.08
	Herbaceous						
9	Wet graminoid	225484.59	7.57	6666.22	2.76	2150.81	7.21
10	Wet/moist graminoid tundra	55263.77	1.85	2741.97	1.13	58005.74	1.80
11	Mosaic: Wet graminoid-erect dwarf scrub	67741.92	2.27	5072.55	2.10	72814.48	2.26
	Shrub						
12	Dry prostrate	5291.22	0.18	30.27	0.01	5321.49	0.17
13	Low shrub	327699.73	11.00	12428.74	5.14	0128.47	10.56
14	Medium shrub	28370.96	0.95	2859.95	1.18	31230.91	0.97
15	Tall shrub	135590.71	4.55	31697.28	13.11	7287.98	5.19
	Dwarf Scrub						
16	Dwarf scrub graminoid tussock	766196.32	25.71	41119.67	17.00	7315.99	25.06
17	Erect dwarf scrub/dwarf scrub-lichen	634881.94	21.31	41720.08	17.25	676602.02	21.00
	Water						
18	Offshore	7464.90	0.25	0.00	0.00	7464.90	0.23
19	Clear	398422.68	13.37	323.67	0.13	398746.35	12.38
	Other						
20	Shadow	24308.97	0.82	5865.06	2.43	0174.03	0.94
Total		2979786.04	100.00	241819.05	100.00	3221605.08	100.00

CONCLUSIONS

The digital data base produced for the SNWR can be used by regional and local resource planners, refuge managers, and researchers. As an example of applications, swan nesting areas on the Refuge were digitized and entered into the IDIMS Systems as an image mask. This image mask was used with the land cover data to obtain data files with pixel counts of each land cover class within each swan territory. After manipulation and summarization, the final files gave hectare estimates for each land cover class within each swan nesting area. The data also may be used to determine habitat use by radio-collared animals (Douglas and others, 1988). Locational data from the animals' movements can be matched with the individual pixels in the data base. The result is a list of habitats and terrain that the animals traversed.

Finally, the land cover may be manipulated to show various habitat types or may be used in conjunction with terrain data to determine possible habitat locations. The fact that the data base is georeferenced also allows other data to be included for further manipulation, enhancement, or update.

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APPENDIX A

VEGETATION DESCRIPTIONS FOR THE SELAWIK NATIONAL WILDLIFE REFUGE LAND COVER MAP*

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 Floodplain

This subclass is a result of the initial invasion of plants on recent river alluvium. Plant cover averages 5 to 20 percent.

Within the refuge, this cover type is found in many locations where current or recent rivers have produced bars or beaches as a result of overflow from water channels. Slopes that produce such flooding conditions are frequently in the lower 2 to 4 percent ranges, particularly in the western half of the Refuge and near the Seward Peninsula. Exposed soils of these areas are typically fine to coarse sands, light tan to light gray, and may form beaches 50 m wide.

Vascular plant species include grasses like Arctagrostis latifolia, Bromus spp., and Festuca rubra. Non-graminoid species include Epilobium latifolium, Crepis nana, Hedysarum alpinum, H. mackenzii, Artemisia tilesii, A. arctica, Salix alaxensis, S. lanata, Astragalus sp., Aster sibericus, and Equisetum sp.

A part of the Scarcely Vegetated Floodplain subclass is less vegetated (less than 5 percent cover) and consists of alluvium which includes silt, sand, and rocks. The plant species that are part of the cover of this grouping are similar to those of the Scarcely Vegetated subclass, and further studies will be needed to determine if this grouping should be considered distinct subclass.

Scarcely Vegetated Scree

This subclass, with 5 to 20 percent plant cover, is composed of more or less unstable steep slopes with stones and weathering rocks. This type of fellfield often grades into the Dry Prostrate Shrub subclass.

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*From: USFWS, 1987, Selawik National Wildlife Refuge, Comprehensive Conservation Plan, Environmental Impact Statement and Wilderness Review, Final, U.S. Fish and WildlifeA Service, Region 7, Anchorage, Alaska, p. 262-268.

The main locations of this subclass within the refuge include the slopes and mountaintops lying near or above the 300 m elevation in the Hockley and Waring Mountains to the north, in the northeast corner of the Selawik Hills along the southern boundary, and places in the eastern extension of the refuge where the Purcell Mountains and Zane Hills enter the boundary. This subclass is not as abundant within the refuge as it is to the north where the taller Brooks Range present many locations with the 5 to 20 percent cover.

Some of the shrubs commonly found in this type in prostrate or decumbent forms include Betula nana, Dryas integrifolia, D. octopetala, Vaccinium uliginosum, Cassiope tetragona, and Salix phlebophyla. Other species that may occur include Cystopteris sp., Diapensia lapponica, Cetraria sp., Lupinus arcticus, Carex bigelowii, Carex sp., crustose lichens, Selaginella siberica, Minuartia arctica, Smelowskia calycina, Draba spp., Saxifraga eschscholtzii, Saxifraga sp., Oxytropis nigrescens, Arctostaphylos alpina, Silene acaulis, Androsace chamaejasme, Loiseleuria procumbens, Salex arctica, Empetrum nigrum, Phyllodoce caerulae, and numerous other lichen species.

Within the Scarcely Vegetated Scree subclass, there are sites with less than 5 percent plant cover and less vegetation than the Scarcely Vegetated condition described. A cover dominated by blackish lichens that may include the genera Umbilicaria, Cetraria, Corniculata, and Pseudophebe may occur. Occasionally, a few dwarf individuals from the genera listed for the Scarcely Vegetated condition may be found as small outcrops of life in these borderline habitats. Often, the sites of this grouping are devoid of flowering plants except in extremely small sites (microsites) that are slightly sheltered, such as crevices. This grouping may be separated from the Scarcely Vegetated Scree in the future if additional studies indicate a distinct character.

Barren Dunes

A barren subclass is characterized by a predominance of dry, coarse-grained sands and sparce vegetation. The plants provide less than 5 percent cover and are usually less than 2 m tall (more commonly less than 1 m).

There appear to be two localities for such dunes: along the coast and scattered within the interior. Coastal sand dunes, which were not clearly indicated on the map products due to the quality of the satellite data, may have a vegetation component including such species as Elymus arenarius, Arctagrostis latifolia, Epilobium anguistifolium, E. latifolium, Angelica lucida, Conioselium chinense, Carex sp., Ligusticum scoticum, Achillia borealis, Lathyrus maritimus, Lupinus arcticus, Valariana capitata, Aconitium delphinifolium, Artemisia tilesii, Potentilla sp., Wilhelmsia physodes, Mertensia meritima, and Gentiana propinqua. The interior dunes of the refuge are much smaller than the larger conspicuous dunes to the north of the refuge near the Waring Mountains. The vegetation of these interior sites will have many of the same species listed for the coast and may also include Spirea sp., dwarf Salix, dwarf Betula, and occasional short Picea glauca (0.3 to 2 m)

FOREST

Forests are formed of tree species at least 5 m tall. Included within the concept of forest is secondary tree growth that is temporarily less than 5 m in height, that is, in 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-Tall Shrub, and (5) Open Forested Dunes.

Closed Needleleaf Forest

This forest subclass is defined as having a percentage of ground cover that may range from 60 to 100 percent. Major tree species are Picea glauca and P. mariana.

In the northwest part of the state, there are two types of white spruce forest: the upland type with large densely growing trees and a sparse shrub understory, and a lowland type that is found on well-drained floodplains and dry slopes. Associated understory species include Salix sp., Alnus crispa, Rosa acicularis, Betula nana, Vaccinium uliginosum, V. vitis-idaea, Empetrum nigrum, Ledum palustre, Epilobium angustifolium, Equisetum sylvaticum, Lycopodium sp., Pyrola sp., Carex sp., Oxycoccus microcarpus, lichens, and mosses.

Open Needleleaf Forest

This subclass contains open stands of Picea glauca and P. mariana, and has an overall 30 to 60 percent cover value. Within the refuge, this subclass occurs as bands along parts of the Selawik and Kugarak Rivers, on islands and banks of the Kobuk River drainage, in intermountain passes of the Waring Mountains, as pockets in the more interior parts of the Kobuk River Delta, and in the southern parts of the eastern end of the Refuge near the Purcell Mountains.

The shrub layer usually consists of Salix glauca and Alnus crispa on alluvial and moist to well-drained sites. The dwarf shrub layer is the more common understory occurring with this subclass. Plant species frequently found include Ledum palustre, Vaccinium uliginosum and V. vitis-idaea, Betula papyrifera, Empetrum nigrum, Eriophorum vaginatum, Arctostaphylos rubra, Dryas integrifolia, Rhododendron lapponicum, Salix reticulata, S. lanata, S. alaxensis, S. planifolia, Carex bigelowii, Festuca altaica, Equisetum arvense, Hylocomium splendens, Potentilla fruiticosa, Rosa acicularis, Epilobium latifolium, Rubus arcticus, Ribes triste, Calamagrostis candensis, Spirea beauverdiana, Aconitium delphinifolium, Boschniakia rossica, Pyrola sp., Mertensia paniculata, Galium boreale, Artemisia tilesii, Peltigera sp., and various lichens.

Some spectral classes of this forest subclass represented reflectance values that appeared to indicate a greater lichen component than that of the described Open Needleleaf condition. However, current data do not confirm the existence of a discrete cut-point between the spectral class grouping and the established land cover subclass. Future studies will determine if splitting the subclasses would be more accurately represented of what is on the ground.

Needleleaf Woodland

This subclass is dominated by a shrub layer, but contains an important stratum containing Picea mariana or P. glauca with a 5 to 30 percent cover of trees greater than 3 m in height. The class occurs in moderately well-drained riparian floodplains with low slopes and near the peripheries of boggy areas that may contain small lakes or potholes. Frequently, this class will be near, and integrating areas of Open Needleleaf. A tussocky tundra is also a common component of the ground surface within the subclass, and may be evident in neighboring communities.

Major shrub species include Betula nana and B. glandulosa, Ledum palustre, Rubus chamaemorus, Vaccinium uliginosum and V. vitis-idaea, Salix reticulata, S. glauca, S. lanata, Alnus crispa, and Dryas integrifolia. Other species may include Epilobium angustifolium, Lupinus arcticus, Potentilla sp., Equisetum arvense and E. scirpoides, Eriophorum vaginatum, Carex bigelowii, C. scirpoides, Calamagrostis canadensis, Festuca sp., Cetraria sp., Cladina sp., Sphagnum sp., Polytrichum sp., Hylocomium splendens, and Dicranum sp.

Deciduous Forest-Tall Shrub

Tree species include Betula papyrifera, Populus tremuloides, and P. balsamifera with 25 to 100 percent tree cover. Salix alaxensis may also be classified in this class on alluvial terraces or by itself or mixed with P. balsamifera. This type is normally found on well-drained to moist soils associated with hills and alluvial terraces, riparian areas, drier margins of lake and bog areas, and similar mesic locations.

Plant species that may occur include Alnus crispa, Salix sp., Rosa acicularis, Shepherdia canadensis, Calamagrostis canadensis, Ribes triste, Vaccinium vitis-idaea and V. uliginosum, Festuca altaica, Aconitium delphinifolium, Bupleurum triradiatum, Equisetum arvense, Galium boreale, Epilobium angustifolium, Linnaea borealis, Ledum palustre, Rubus arcticus, Spirea beauverdiana, Oxycoccus microcarpus, Carex sp., Delphinium glaucum, Polomonium acutiflorum, Aster sibericus, the mosses Rhytidium rugosum and Polytrichum sp., and the lichens Cladonia mitis, Cladonia sp., and Cetraria nivalis.

An apparent subgroup of the forest class that has a mixed character (namely broadleaf and evergreen needleleaf tree species) with 25 to 100 percent coverage. This subgroup occurs on well-drained to moist sites in the uplands. Primary species include Picea glauca and Betula papyrifera and occasionally Populus balsamifera, P. tremuloides, or Salix sp. (some over 5 m tall).

This mixed subgroup is only moderately abundant and is largely restricted to the north half of the refuge near the Waring Mountains and Kobuk River drainage. Understory species common to the needleleaf and deciduous classes may be found in this subgroup. Further studies will be required to determine whether this assemblage is sufficiently distinct to be separated as a major subclass.

Open Forested Dunes

This subclass occurs southeast of the Waring Mountains in an area that is heavily influenced by active and inactive eolian sand dunes formed principally during the Pleistocene epoch. Tree species in this category may include Picea glauca or Populus tremuloides. Plant cover of 30 to 60 percent is normal. Understories are usually poorly developed and sparse, but when present may include numerous lichen species (with cover values of 50 to 100 percent coverage), Shepherdia canadensis, Lupinus arcticus, Spirea beauverdiana, and Empetrum nigrum.

HERBACEOUS (GRAMINOID)

Herbaceous species are without significant woody tissue and die back to the ground each year. Their growth forms are: graminoids and forbs. Graminoid forms include all non-woody grasses and grass-like plants such as Carex and Eriophorum. Forbs are broad-leaved herbaceous plants like Petasites and Epilobium. Three subclasses of the herbaceous type are recognized: (1) Wet Graminoid, (2) Wet/Moist Graminoid Tundra, and (3) Mosaic: Wet Graminoid-Erect Dwarf Shrub.

Wet Graminoid

This class represents a composite grouping of very wet (with standing water and emergents) and wet (with wet soils and occasional standing water) graminoid communities. The communities in this subclass are graminoid-dominated formations that may be associated with open water bodies that are fresh or brackish, low areas near river channels, low-center polygons, strangmoor, deltas, and other poorly drained sites. The subclass, while found throughout most of the refuge, is very common in the regions near the coast, the wetter interior near Inland and Selawik Lakes, and in the major river drainages.

Major species in these sites include Arctophyla fulva, Carex sp., and Eriophorum sp. in deep water. Other species that may occur include Equisetum fluviatile, Scirpus sp., Pedicularis sp., Valeriana capitata, Polygonum sp., Tomenthypnum nitens, Drapanocladus sp., Calamagrostis canadensis, Ledum palustre, Empetrum nigrum, and Sphagnum sp.

Wet/Moist Graminoid Tundra

This subclass, while having moist to wet soils, is usually restricted to areas with polygonal ground features and tussocky surfaces. Although the graminoid component of the community is evident, frequently a distinction can be made between the wetter polygon centers, the drier polygon rims, and the tops of tussocks. This subclass also represents drained lake basins that have been overgrown by grass and forb species, giving a meadow-like effect.

The high degree of variation in surface morphology often results in very complex vegetation patterns at the microsite level within this subclass. Frequently encountered plant species include dwarf Betula sp., dwarf Salix sp., Alnus crispa, Carex bigelowii and Carex sp., Eriophorum angustifolium, Vaccinium uliginosum, Calamagrostis canadensis, and Ledum palustre. Other species that may be found include Epilobium angustifolium, Rubus chamaemorus, Picea glauca (rare), Oxycoccus microcarpus, Myrica gale, Empetrum nigrum, and Aconitium delphinifolium.

Mosaic: Wet Graminoid-Erect Dwarf Shrub

This herbaceous class represents a transition stage from the wet, predominantly graminoid communities to the wet graminoid/dwarf shrub communities. In some respects, the character of this class can be likened to a wet savannah-like situation with plants of reduced stature. The dominant feature is that of a graminoid marsh or bog with Calamagrostis canadensis, Eriophorum angustifolium, and Carex sp. being evident, and raised dwarf scrub or peat hummocks with small Salix sp., Betula sp., Ledum palustre growing locally.

SHRUB

This vegetation class is composed predominantely of shrubs that provide greater than 25 percent cover, are 0.5 to 5 m in height, and shed their foliage annually.

Dry Prostrate

This formation occupies slightly elevated microsites in the interior, upper slope positions in the foothills and mountains, and may occur on dry alluvial terraces or fans above several hundred 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 usually achieve heights greater than 20 to 25 cm. Some of the more commonly occurring species are Dryas integrifolia and D. octopetala, Arctostaphylos rubra, Salix phlebophyla and Salix sp., Saxifraga sp., Carex sp., Festuca sp., Equisetum sp., Lupinus arcticus, Bupleurum triradiatum, Androsace chamaejasme, Alectoria nigrescens, Silene acaulis, Arnica sp., Phlox sp., Selaginella sp., Hierochloe alpina, and Diapensia lapponica.

Low/Medium/Tall Shrub

These subclasses are based primarily on height differences although certain species are more prevalent in one subclass than another. Separation of these vegetation subclasses was accomplished using winter Landsat MSS data in combination with solar illumination, slope, aspect, elevation, and summer Landsat MSS data.

Low Shrub. This is a subclass with plant forms from 0.5 to 1.0 m high. Frequently the low shrubs have such characteristic species present as Betula nana, B. glandulosa, Salix planifolia, S. lanata, S. glauca, S. hastata, Shepherdia canadensis, and Vaccinium uliginosum.

Medium Shrub. The medium shrub subclass ranges from 1.0 to 3.5 m in height. Species may include those mentioned for the Low Shrub subclass, plus Salix alaxensis and Alnus crispa.

Tall Shrub. This subclass normally has plants in the 3.5 to 5 m height range. The species listed for the Low and Medium Shrub may be fewer in number than in those communities, plus Betula papyrifera and Populus tremuloides.

Within any of the low, medium, or tall shrub communities, other species that might occur are Salix brachycarpa, S. reticulata, Arctostaphylos rubra, Potentilla palustris, Dryas integrifolia, D. drumondii, Equisetum sp., Carex aquatilis, and Petasites sp.

DWARF SCRUB

This class is composed chiefly of dwarf species primarily from the genera Betula and Salix and ericacious species. These shrubs are usually 0.1 to 0.5 m in height and occur in areas with a shallow active soil layer, in burn areas, or in areas underlain by permafrost. Graminoid species such as Carexaquatilis, C. bigelowii, Calamagrostis canadensis, and Eriophorum vaginatum are often mixed with the shrubs and may produce tussocks.

Dwarf Scrub Graminoid Tussock

This subclass is common in rolling hills and includes species like Betula nana, Salix lanata, S. pulchra, Vaccinium vitis-idea, V. uliginosum, Empetrum nigrum, and Ledum decumbens. Carex bigelowii is the main tussock-producing graminoid which may, at times, appear to dominate the sites of this subclass. Other species that may occur include Pedicularis sp., Oxycoccus microcarpa, Equisetum sp., and lichen species.

Erect Dwarf Scrub/Dwarf Scrub-Lichen

This subclass is common on the refuge, especially in the northern and western parts. Fruticose and crustose lichens are a common, if not major component of this type along with erect dwarf shrubs. The associated plant species for this subclass include many of the same species given above for the Dwarf Shrub Graminoid Tussock subclass.

WATER

Offshore Water

Offshore waters include the shoreline and waters seaward from the terminus of the Kobuk River delta to the refuges southern coastal boundary of the refuge where it touchs the coast.

Clear Water

This subclass comprises clear water including lakes, ponds, and rivers.

OTHER

Shadow

The shadow class represents those areas obscured from the sensor by clouds or shadows in mountainous terrain or a reduced level of vegetation reflectance with corresponding unusable data.

Digitized Streams

Stream courses derived from 1:250,000-scale USGS topographic maps, were digitized and incorporated into the land cover data.