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LAND USE/VEGETATION MAPPING IN RESERVOIR MANAGEMENT. MERRIMACK RIVER BASIN

H. L. McKim, et al

Cold Regions Research and Engineering Laboratory

Prepared for:

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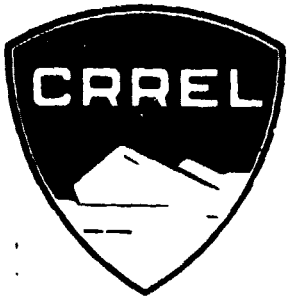

Special Report 233

LAND USE/VEGETATION MAPPING IN RESERVOIR MANAGEMENT

MERRIMACK RIVER BASIN

H.L. McKim, L.W. Gatto, C.J. Merry
D.M. Anderson and T.L. Marlar

July 1975

PREPARED FOR
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BY

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The purpose of this investigation was to demonstrate the extent to which ERTS-1 imagery, Skylab S190A and S190B photography, and RB-57 photography can be utilized in the preparation of land use/vegetation maps. The analysis was accomplished with black and white enlargements (1:63, 360 scale) of the original NASA photography acquired on cloud-free days within a 47-day period. Ancillary data were not used during the mapping exercise to eliminate bias in the comparisons and to ensure that the results were derived strictly from interpretations of tones and textures on the photography. The classification scheme was a modified version of the U.S. Geological Survey Land Use Classification System for use with remote sensor data. The mapping units delineated from each of the data products are

20. Abstract (cont'd)

as follows: ERTS-1 MSS band 5 – 5 individual level I, 2 combined level I, and 8 level II; S190A – 6 level I and 13 level II; S190B – 6 level I, 17 level II and 1 level III; and RB-57 – 6 level I, 21 level II and 5 level III. This investigation demonstrates that for land use/vegetation mapping the Skylab S190B photography compares favorably with the RB-57 photography and is much superior to ERTS-1 imagery and Skylab S190A photography. The 12.5-m resolution of the S190B photography is sufficient to accomplish rapid land use and vegetation surveys required in many of the management problems of reservoirs or watersheds. The ERTS-1 and S190A data products are not considered adequate for this purpose, although they are useful for rapid regional level I surveys of land use and vegetation.

PREFACE

This report was prepared by Dr. H.L. McKim, Research Soil Scientist, L.W. Gatto, Geologist, C.J. Merry, Geologist, and Dr. D.M. Anderson, Supervisory Research Physical Scientist, Earth Sciences Branch, Research Division, and T.L. Marlar, Supervisory Photographer, Technical Services Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was funded by the National Aeronautics and Space Administration under Contract EPN089, *New England Reservoir Management*, with the New England Division, Corps of Engineers (Saul Cooper, Principal Investigator).

The report was technically reviewed by Paul V. Sellmann, U.S. Army Cold Regions Research and Engineering Laboratory, and by Saul Cooper, Joseph Horowitz and Lt. Colonel Arcade Boivin, New England Division, Corps of Engineers.

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INTRODUCTION

This report consists of an analysis of: ERTS-1 Multispectral Scanner imagery obtained 10 August 1973; Skylab 3 S190A and S190B photography, track 29, taken 21 September 1973; and RB-57 high-altitude aircraft photography acquired 26 September 1973. These data products were acquired on three cloud-free days within a 47-day period. It is known that atmospheric haze and sun angle variations limit the tonal contrast of, and thus the amount of information observable on, satellite and aircraft imagery. It is also evident that these parameters change not only from day to day but continually during image acquisition. Therefore, the interpretations made from imagery acquired on different days when atmospheric conditions are similar are as useful as those made from imagery acquired on the same day. Due to processing delays, the last of the S190B photography from NASA was not received until 24 May 1974.

The objectives of this study were:

1) To make quantitative comparisons between high-altitude aircraft photography and satellite imagery.
2) To demonstrate the extent to which high resolution (S190A and B) space-acquired data can be utilized for land use/vegetation mapping and management of drainage basins.

The test site chosen for this investigation was a 124-km^2 area of the Merrimack River estuary (Fig. 1). This area contains the largest variety of land use and vegetative classification units to be found in the Merrimack River Basin. In addition, the Merrimack River Basin is a primary test site for the NED-CRREL Skylab Earth Resources Experiment Package (EREP) project.

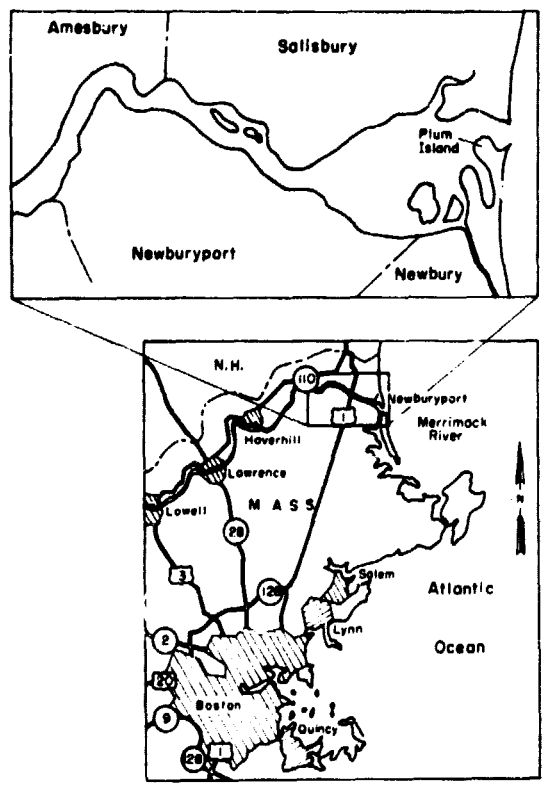

Figure 1. Location map.

SPECIFIC COMPARISONS OF IMAGERY

Resolution

The general characteristics of the ERTS-1 imagery and Skylab and aircraft photography received from NASA are given in Table I. The minimum size of detectable objects (ground resolution) was determined by inspection of the NASA data products (Table II). The smallest features that can be recognized on the ERTS-1 imagery are linear features such as roads, bridges, etc. about 70 meters in width that contrast sharply with the surrounding terrain (McKim et al. 1972*). The minimum size of circular or oblate objects detectable on the Skylab S190A photography is about 4900 m^2, whereas on the ERTS-1 imagery the minimum size is about 24,300 m^2. As might be anticipated, mapping accuracy obtained when using Skylab photography is superior to that obtained when using ERTS-1 imagery, increasing as the photographic scale decreases. In line with this, the RB-57 photography at a scale of 1:120,000 offers the best mapping tool of all the data products analyzed when accuracy is considered. This effect, however, is offset by a reduction in ground coverage.

Table I. Characteristics of NASA data products.

Imagery	*Transparency dimension (cm)*	*Scale*	*Estimated ground coverage (km)*	*Area (km^2)*
ERTS-1 Multispectral Scanner (0.6-0.7 μ)	18.6	1:1,000,000	185	34,344
S190A Multispectral Camera (0.6-0.7 μ)	5.7	1:2,850,000	163	26,595
S190B Earth Terrain Camera (CIR 3443)	11.4	1:830,720	109	11,955
RB-57 RC-8 Camera (CIR 2443)	22.9	1:120,000	28	773

Table II. Ground resolution.

	ERTS-1	*S190A*	*S190B*	*RB-57*
Linear features (width, m)	70	25	12.5	5
Circular features (area, m^2)	24,300	4,900	3,200	800

Table III. Land use/vegetation classification system.

Modified from Anderson et al. (see footnote, p. 3).

Level I	*Level II*	*Level III*
Urban/built-up land (U)	1. Residential-single	
	2. Residential-multi	
	3. Commercial	Parking lot, U_{3p}
	4. Industrial	
	5. Extractive	
	6. Mixed	
	7. Transportation, communications, utilities	
	8. Institutional	School, U_{8s}
	9. Open and other	Park, U_{9p}
		Cemetery, U_{9c}

* McKim, H.L., T.L. Marlar and D.M. Anderson (1972) *The use of ERTS-1 imagery in the National Program for the Inspection of Dams*. U.S. Army Cold Regions Research and Engineering Laboratory Special Report 183 (AD 754579).

Agricultural land (A)	1. Pasture 2. Row crop 3. Orchard	
Forest land (F)	1. Deciduous 2. Coniferous 3. Mixed	
Water (W)	1. Stream 2. Lake 3. Reservoir 4. Bay/estuary 5. Tidal channel 6. Ocean	
Nonforested wetlands (N)	1. Vegetated 2. Bare	Tidal marsh, N_{1a}
Barren land (B)	1. Beach 2. Bare exposed rock 3. Other	

Scale

Imagery from the three satellite data products was enlarged to approximately 1:800,000, 1:400,000, 1:200,000, and 1:63,360 to determine the most useful scale for mapping. The detail on the small-scale imagery (1:800,000 - 1:200,000) was sufficient but not practical for level I (see Table III) land use/vegetation mapping. At this scale, all the mapping units detectable on the imagery could not be delineated because the test site was extremely small. However, the units on the 1:63,360 scale were of sufficient dimension to enable accurate mapping and data transfer to be accomplished. Additional reasons for selecting a 1 in.:1 mile scale are: 1) this scale corresponds to that of the 15-minute quadrangle sheets; and 2) at larger scales the S190A photograph begins to have a "grainy" appearance and the scan lines on the ERTS-1 imagery become prominent, reducing image clarity.

LAND USE/VEGETATION MAPPING

The classification scheme (Table III) selected for this project is a modified version of the U.S. Geological Survey Land Use Classification System (Anderson et al. 1972*).

Land use/vegetation maps were prepared from black and white contact prints of an ERTS-1 MSS band 5 (0.6 to 0.7 μ) image, an S190A (0.6 to 0.7 μ) photograph, an S190B color infrared (CIR) photograph and an RB-57 CIR photograph. The 0.6 to 0.7 μ wavelength of the ERTS-1 multispectral imagery and the S190A photography was selected because land use and vegetation patterns are most prominently displayed on this band. All imagery was contrast enhanced photographically to portray the maximum number of gray tones.

The maps from the RB-57 and S190B photography were prepared simultaneously by different image analysts; next, the S190A and ERTS-1 maps were compiled. Although mapping from the most detailed photography was actually done first, this information did not bias the preparation of the maps on the less detailed imagery. In all of the analyses, unit designations were based strictly on the tone and texture of the photographs. This approach is somewhat different from conventional land use mapping methods; only information extractable from the imagery alone without reference to ancillary data entered into the interpretation of units. This was done to eliminate bias in the comparisons insofar as possible and to ensure that the results were derived strictly from interpretations of the various tones and textures intrinsic to the imagery. During the exercise, the only references made were to the original color, CIR and false color renditions of the various NASA data products being compared.

* Anderson, J.R., E.E. Hardy and J.T. Roach (1972) *A Land Use Classification System for Use with Remote-Sensor Data*. U.S. Geological Survey Circular 671, 16 p.

ERTS-1 imagery

Five individual level I, two combined level I, and eight level II units were delineated on the ERTS-1 MSS band 5 image (Fig. 2a, b). Open water was included in the N_1 (vegetated, nonforested wetland) and F_3 (mixed forest) units on the ERTS-1 MSS band 5 map. Tidal channels and intermittent streams also have reflectance characteristics similar to those of the N_1 unit on this band 5 image. These similarities may result from high reflection from suspended particulates in stream beds. The boundary between inland water and the F_3 unit also was not apparent on the band 5 print because of similar signatures; however the boundary between these units and water is clearly defined on the band 7, near infrared, scene (Fig. 2c). This clearly illustrates that both ERTS-1 MSS bands 5 and 7 are required for land use/vegetation mapping using conventional photointerpretation techniques.

Since the tonal differences between urban built-up land (U) and agricultural land (A) were not significant, these units were combined to form either A-U or U-A. The U-A unit was used when light gray tones from highly reflective surfaces (i.e., pavements, buildings, etc.) predominated, whereas the A-U unit was used when the primary tone was dark gray with a few scattered light gray tones. The only mappable level II urban unit was U_7, the right-of-way for an interstate highway. The coastal area was mapped as B_1 and B_3, which were interpreted to be a sand beach and an area of drifting sand, respectively.

Skylab S190A photography

Six level I and thirteen level II units were mapped on the S190A photograph (Fig. 3a, b). Three level II urban units could be easily distinguished from agricultural and forested lands. The agricultural lands, however, could not be defined to the second level because the tonal contrasts of orchards, row crops and pastures were not significant. The B_3 unit as previously mapped on the ERTS-1 band 5 image was interpreted to be an area where beach sands are encroaching on the tidal marshes. A similar interpretation of this unit was made on the S190A frame, but a more accurate distinction between the B_1 and B_3 units was possible. The B_1 unit comprises primarily white to very light gray tones, while the B_3 unit comprises mottled tones with variations from very light gray to dark gray. Small fields and single family residences not visible on the ERTS-1 band 5 scene, and surrounded by mixed forests, are included in the F_3 unit on the S190A map. Small offshore islands or shoals south of the mouth of the Merrimack River, inland water bodies, and tidal channels not seen on the ERTS-1 band 5 image are apparent on the S190A frame. In all, one more discrete level I and five more level II units were defined on the S190A photograph than on the ERTS-1 band 5 image.

Skylab S190B photography

Six level I units, seventeen level II units, and one level III unit were mapped on the S190B photograph (Fig. 4a, b). Level II agricultural lands could not be delineated, but two previously unmapped urban units, residential-single (U_1) and open and other (U_9), were defined. When U_9 and A units had similar tones, the unit was designated U_9 if it was near an urban area. Marinas not previously recognized were delineated on the S190B photograph and included in U_7. Secondary linear features suggesting utility lines, secondary roads and railroads were easily identified. However, they were not mapped because their complex patterns detracted from the clarity of the mapping units.

One level III unit, N_{1a}, tidal marshes, could be mapped along the southern shore near the mouth of the estuary. The marshes in the N_{1a} unit differ from those in the N_1 unit in that the N_{1a} marshes appear darker and are probably inundated daily. Additional tidal channels not previously distinguished on the S190A print are delineated on the S190B photograph. Many units (U_1, A, U_6, N_1) previously included in F_3 and A units of the S190A map are more clearly defined on the S190B photograph and therefore have been mapped as separate units. In all, on the S190B map, four level II units and one level III unit were distinguished in addition to the units mapped on the S190A photograph.

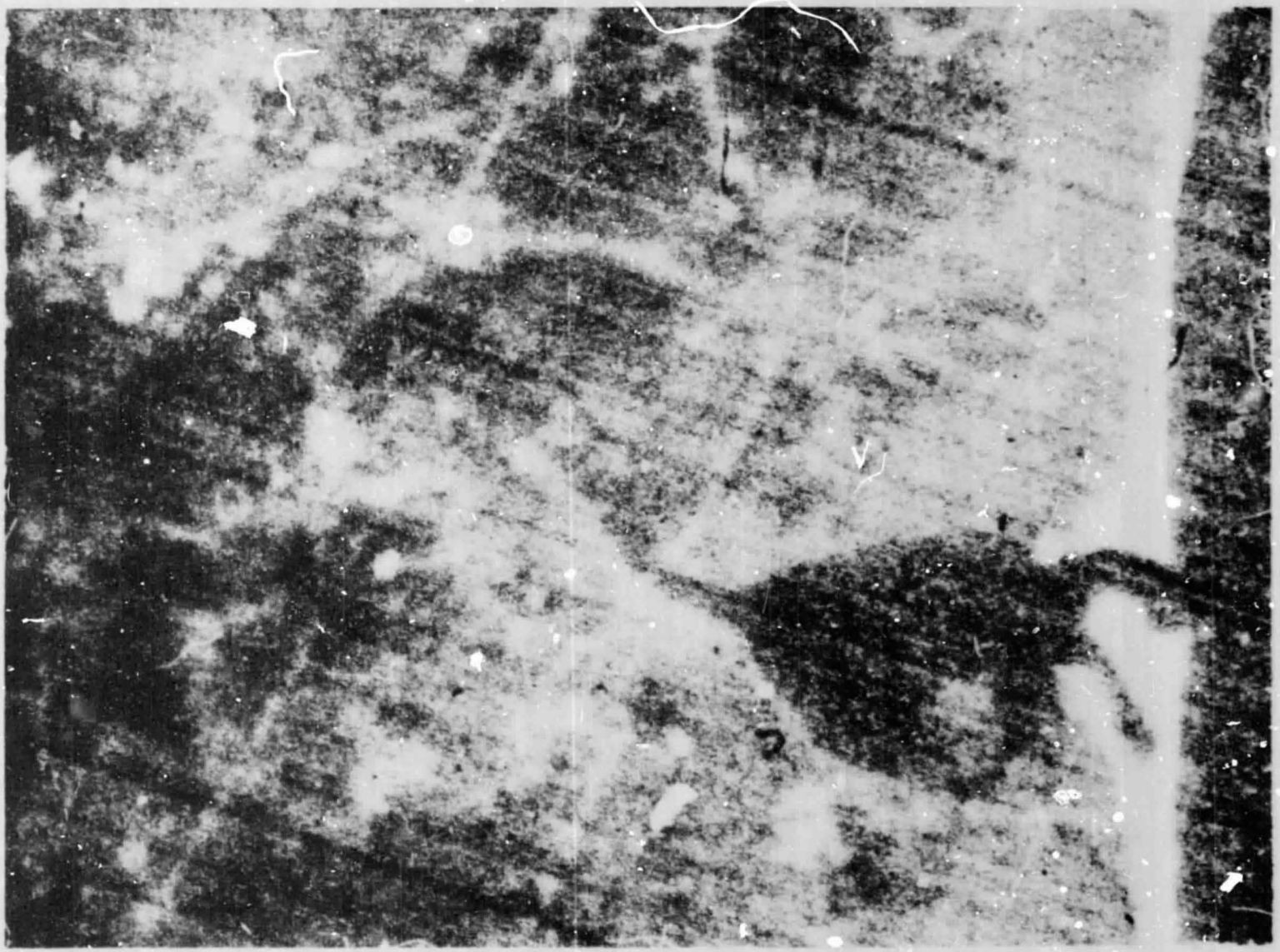

Figure 2a. ERTS-1 MSS band 5 image (ID 1383-15,003) of study area; approximate scale 1:63,360.

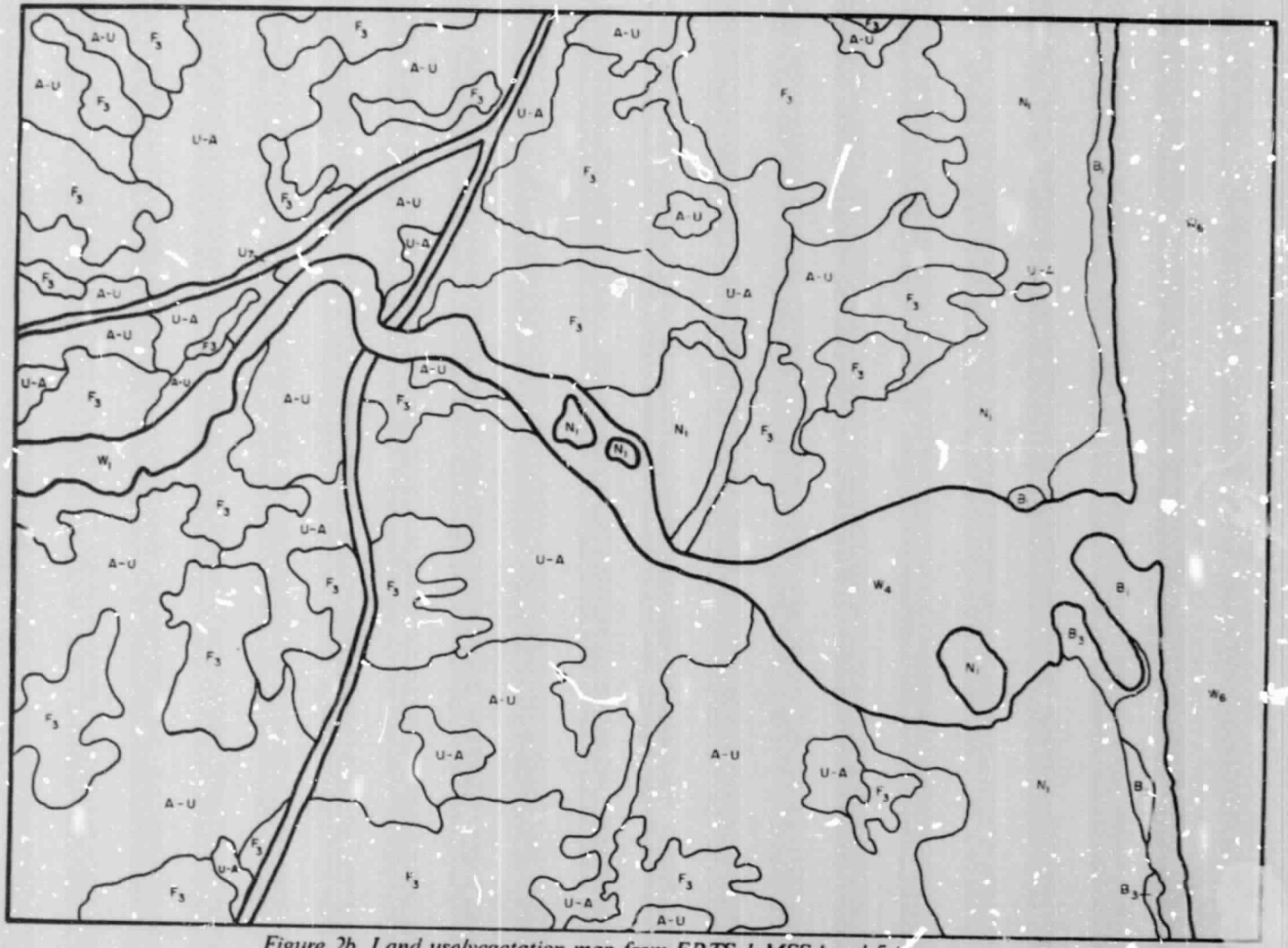

Figure 2b. Land use/vegetation map from ERTS-1 MSS band 5 image.

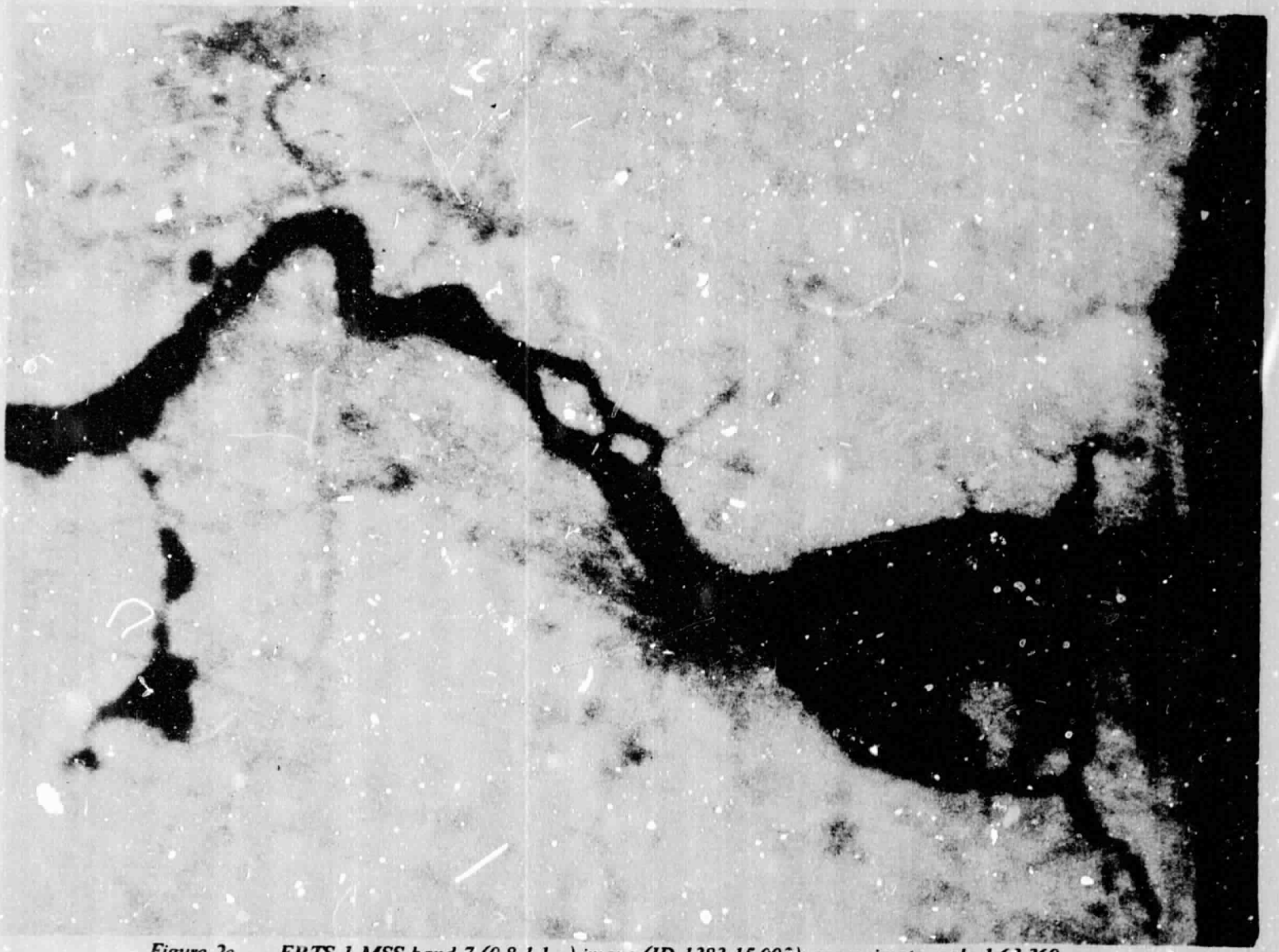

Figure 2c. ***ERTS-1 MSS band 7 (0.8-1.1 μ) image (ID 1383-15,003); approximate scale 1:63,360.***

Figure 3a. S190A photograph (ID 47-306) of study area; approximate scale 1:63,360.

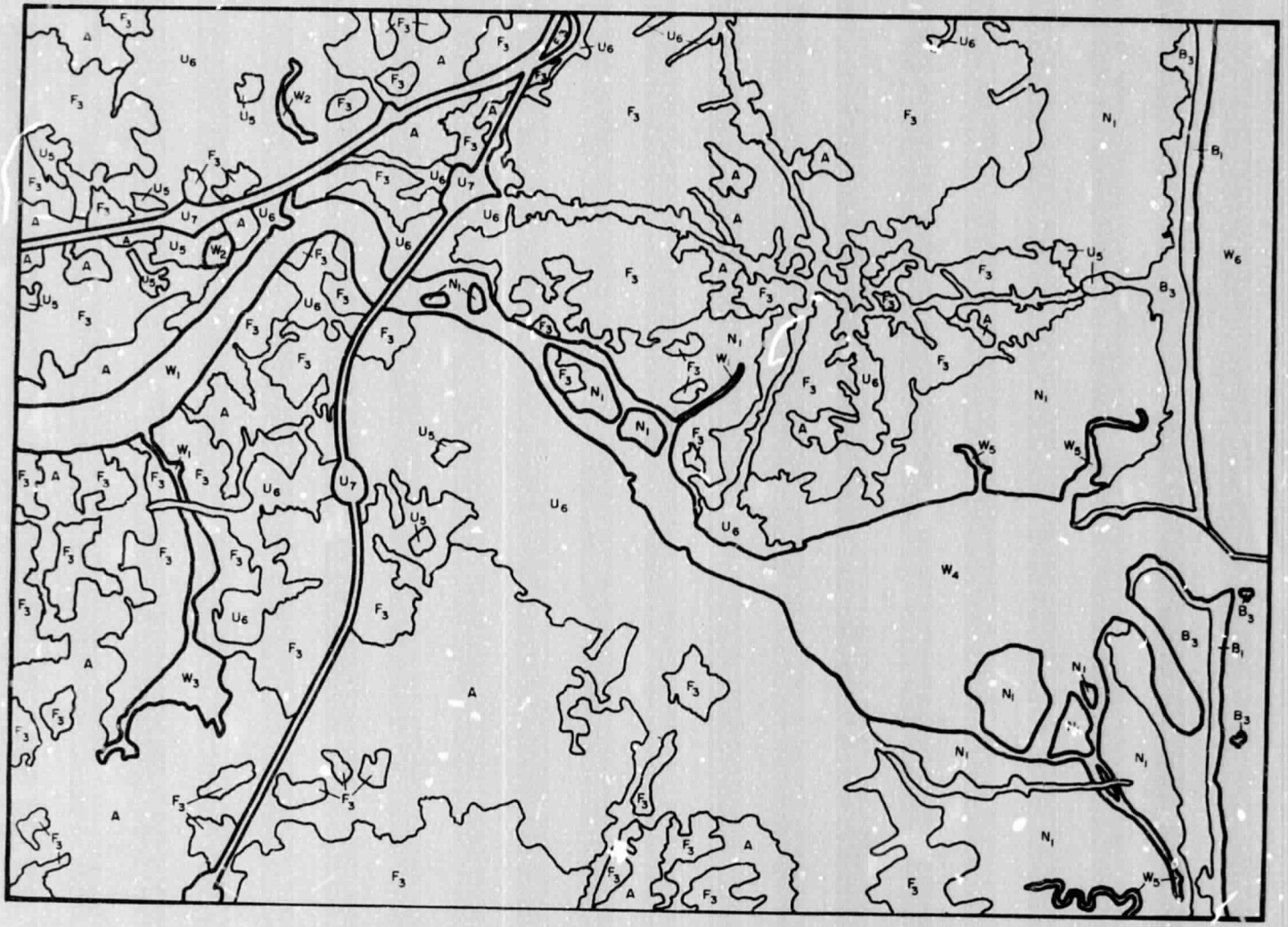

Figure 3b. Land use/vegetation map from S190A photograph.

Figure 4a. S190B photograph (ID 87-305) of study area; approximate scale 1:63,360.

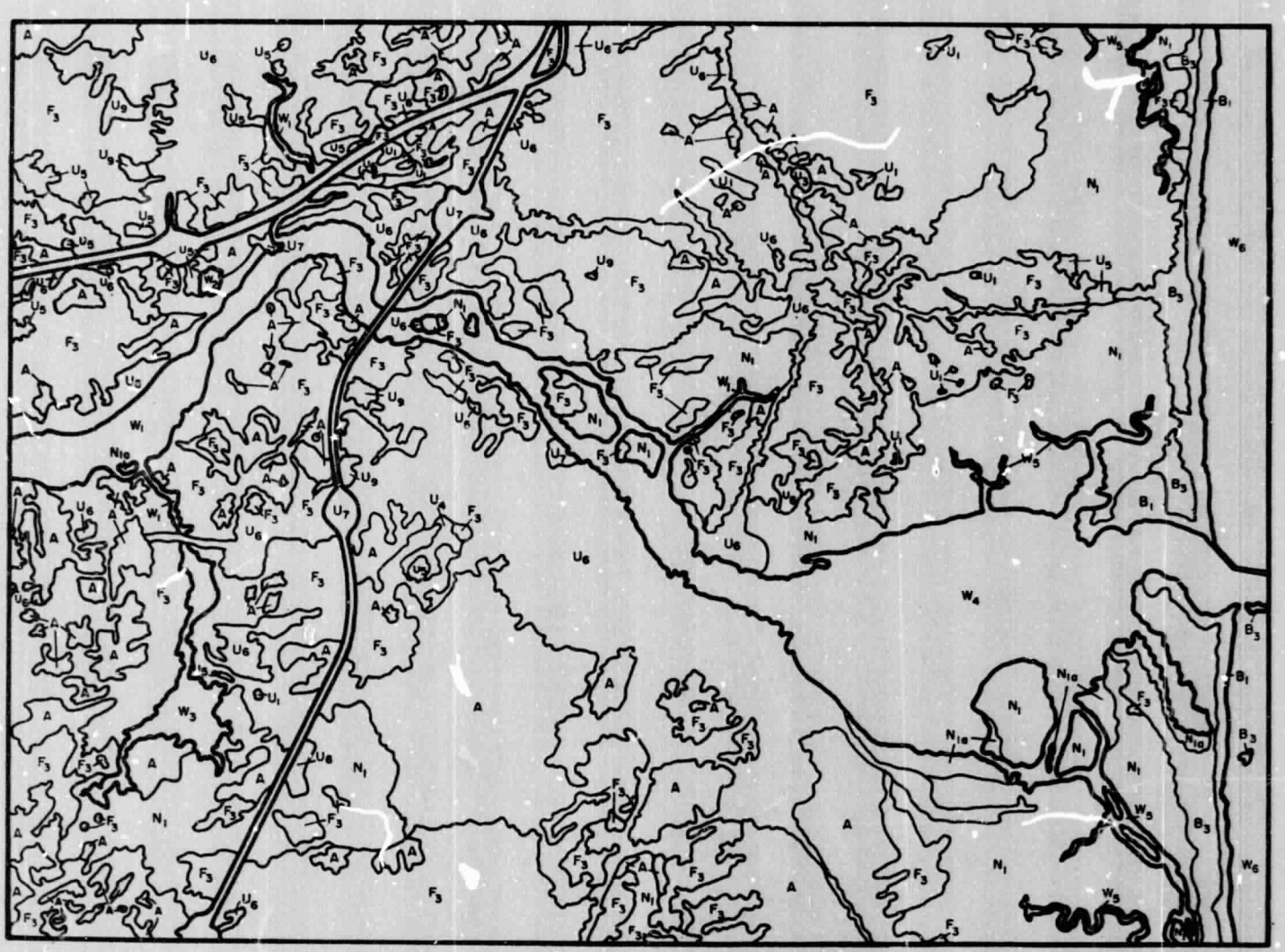

Figure 4b. Land use/vegetation map from S190B photograph.

Figure 5a. RB-57 high-altitude aircraft photograph (ID 151-9085) of study area; approximate scale 1:63,360.

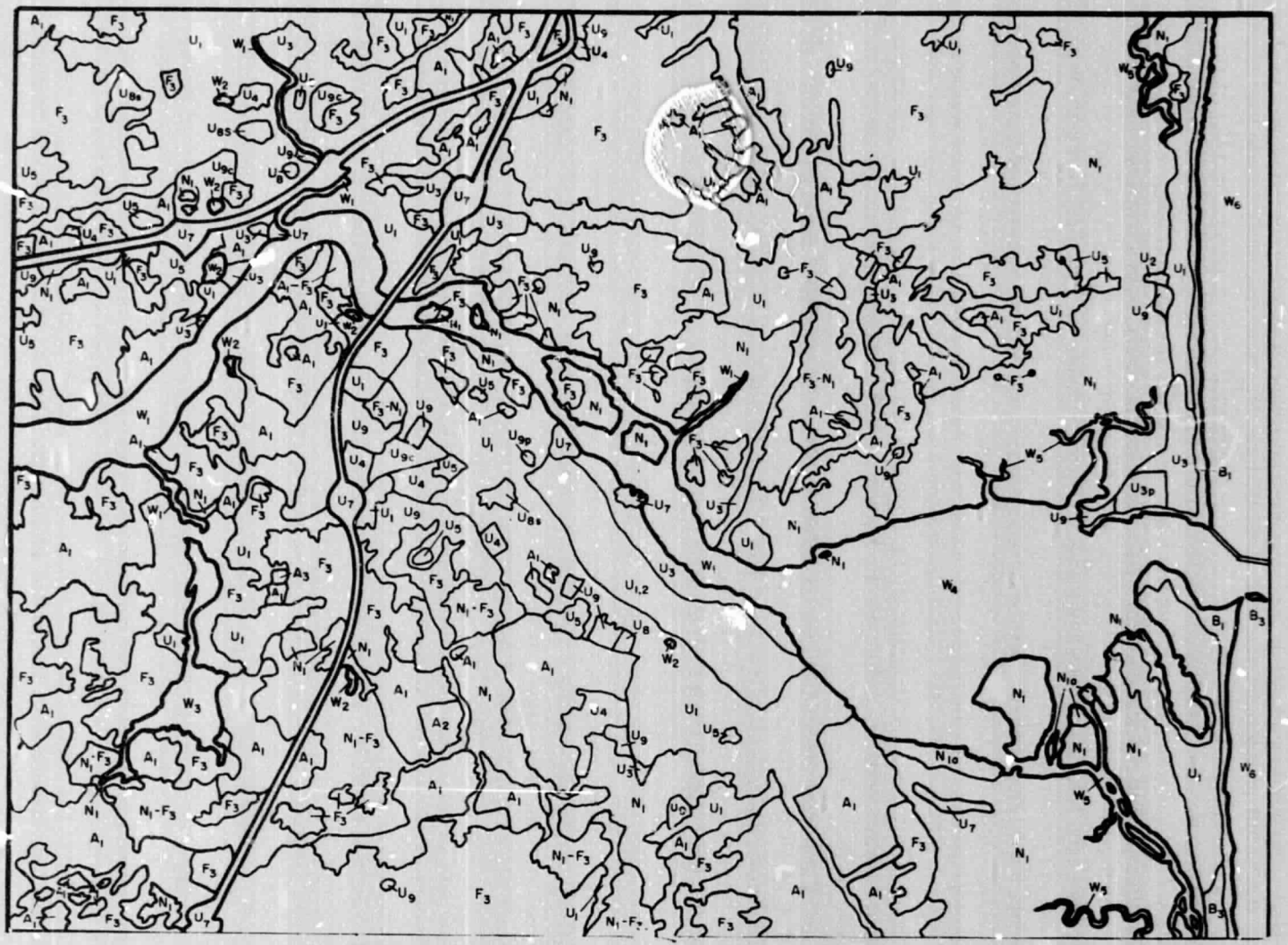

Figure 5b. Land use/vegetation map from RB-57 photograph.

RB-57 high-altitude aircraft photography

Six level I, twenty-one level II and five level III units were mapped on the RB-57 photograph (Fig. 5a, b). Four level III units which include schools (U_{8s}), parking lots (U_{3p}), cemeteries (U_{9c}), and parks (U_{9p}) were previously mapped in the urban unit (U_6) on the S190B photograph; the fifth level III unit, N_{1a}, was previously mapped on the S190B photograph. Urban areas included in the level II, mixed urban unit (U_6) of the S190B map were separated into the following distinct level II units on the RB-57 map: U_1, $U_{1,2}$, U_3, U_4, U_8 and U_9. Agricultural lands were easily divided into level II categories, pastures (A_1 and A_2) and orchards (A_3). For mapping clarity, trees along fence lines and in small groves were not separated but were included in the A_1 and U_1 mapping units, respectively. Roads, railroads and utility lines could readily be identified. However, they were not drawn on the map because of the difficulty in placement of mapping symbols when these lines crossed individual mapping units. Intermittent streams and man-made drainage ditches not previously recognized in the N_1 unit were detected on the RB-57 photograph but were not delineated on the map. Where vegetated, nonforested wetlands (N_1) and mixed forests (F_3) could not adequately be separated, a combined unit was designated. Where the N_1 unit dominated the combined unit, N_1-F_3 was employed, and where mixed forests dominated the unit, F_3-N_1 was used. The same principle was utilized in defining the A_1-F_3 unit.

It was also possible to observe houses, roads, and developed areas on the RB-57 photograph that had been previously mapped as B_3 and B_1 on the satellite imagery. Therefore, portions of each of these barren land (B) units were separated into level II urban units (U_1, U_3, U_9). In all, four more level II and four more level III units were mapped on the RB-57 photograph than on the S190B photograph.

DISCUSSION

Earlier experience has shown that the following factors should be considered in providing remote sensing data useful in the management of reservoirs and watersheds: repetitiveness, scale, ground resolution and interpretation time. ERTS-1 imagery of the study site was available at 18-day intervals. This imagery, however, cannot be enlarged to a scale greater than approximately 1:63,360, and its ground resolution (Table II) is such that only five separate and two combined level I land use/vegetation units could be mapped by conventional methods. Agricultural and urban land could not be easily differentiated, hence the need for combined U-A or A-U units. The eight mappable level II units (Table IV) include water, W_1, W_4 and W_6; barren land, B_1 and B_3; urban areas, U_7; nonforested wetlands, N_1; and forest land, F_3. The ERTS-1 MSS band 5 map took approximately 1.5 hours to prepare and was the least detailed of all the maps prepared. This imagery can be used effectively for mapping land use/vegetation on a regional scale but is much less useful in the analysis of small watersheds using conventional photointerpretation techniques.

Skylab photography for the site is available for 16 and 21 September 1973 (SL3) and for 14 January 1974 (SL4). As in the case with the ERTS-1 imagery, the S190A multispectral photography also begins to lose image quality when enlarged to scales greater than approximately 1:63,360. However, the ground resolution is at least three times better than that of the ERTS-1 imagery and thus mapping detail is improved. Six distinct level I units were mapped from the S190A photograph. The one additional unit was mapped because urban and agricultural lands not separated on the ERTS-1 band 5 image were easily differentiated on the S190A photograph. The thirteen level II units included (Table IV): water, W_1, W_2, W_3, W_4, W_5, W_6; urban areas, U_5, U_6, U_7; barren land, B_1, B_3; forest land, F_3; and nonforested wetlands, N_1. The water/land boundary was more apparent on the S190A photograph than on the ERTS-1 band 5 image; thus an additional infrared photograph was not required in mapping with S190A data. The mapping time increased to

nearly 4 hours with the S190A photography but the product was significantly better than the ERTS-1 band 5 map. The S190A photography is sufficient for mapping land use/vegetation in areas where rapid development is not a factor and repetitive coverage is not essential.

Table IV. Summary of land use/vegetation units mapped.

Categories	*ERTS-1*	*S190A*	*S190B*	*RB-57*
U	•	•	•	•
U_1			•	•
U_2				•
U_3			•	•
U_{3p}				•
U_4			•	•
U_5		•	•	•
U_6		•	•	
U_7	•	•	•	•
U_8				•
U_{8s}				•
U_9			•	•
U_{9p}				•
U_{9c}				•
A	•	•	•	•
A_1				•
A_2				•
A_3				•
F	•	•	•	•
F_1				
F_2				
F_3	•	•	•	•
W	•	•	•	•
W_1	•	•	•	•
W_2		•	•	•
W_3		•	•	•
W_4	•	•	•	•
W_5		•	•	•
W_6	•	•	•	•
N	•	•	•	•
N_1	•	•	•	•
N_{1a}			•	•
N_2				
B	•	•	•	•
B_1	•	•	•	•
B_2				
B_3	•	•	•	•
TOTAL	14	19	24	32

The S190B color infrared photography has a ground resolution nearly twice that of the S190A and the map prepared from the S190B photography is therefore more detailed. The six level I units, previously mapped with the S190A, were delineated, plus a total of seventeen level II units, four more than with the S190A. The level II units, U_1, U_3 and U_4, previously included in the U_6 unit, and the U_9 unit, previously included in the U_6 or A units on the S190A map, were differentiated. Also, since the difference between agricultural, urban and forested areas was more apparent on the S190B scene than on the S190A photograph, additional and more accurate delineations of these categories were made. The water/land boundary was more apparent on the S190B than on the S190A photograph. As a result, additional tidal channels were mapped and many more small streams were detected on the S190B photograph. Soil moisture differences were more apparent on the S190B photograph; therefore, a previously unmapped level III unit, N_{1a}, tidal marshes, was delineated. The distinction in soil moisture also facilitated the differentiation of the agricultural lands, A, and the nonforested wetlands, N_1. The time required for mapping was about 8 hours but the map is considerably more detailed than either the S190A or the ERTS-1 band 5 map.

The RB-57 high-altitude, color infrared photography has a ground resolution that is at least two times greater than that of the S190B. Thirty-two land use/vegetation units were mapped with the RB-57 photograph: six level I previously mapped, twenty-one level II and five level III. The additional level II units are agricultural land, A_1, A_2 and A_3, and urban land, U_2. These urban areas were delineated from the large urban areas classified as mixed, U_6, on the S190B photograph.The four previously unmapped level III units are urban lands, U_{3p} (parking lots), U_{8s} (schools), U_{9p} (parks) and U_{9c} (cemeteries). All the forest land in the area is mixed, F_3. The distinction between the F_3, N_1 and A_1 units was more apparent on this photograph, so more accurate delineations were made. A combined unit, N_1-F_3 or F_3-N_1, was used where the mixed forests and vegetated, nonforested wetlands were in proximity to each other. Urban land, U_1, along the coast was previously mapped as a B_3 unit on the other photographs. Without the high ground resolution of the RB-57 photograph, this unit (U_1) could not have been accurately mapped. Water/land boundaries and nearshore features were very distinctive. There were faint indications of bathymetric features in shallow water. All level III categories as described by Anderson et al. (see footnote, p.3) where applicable could be mapped on the RB-57 photograph. The RB-57 map required 10 hours to draft and clearly provided the most information. However, it may also be the most costly if aerial coverage, etc. is considered when comparing the imagery and photography analyzed in this report.

SUMMARY

The data products provided were enlarged several times to facilitate land use/vegetation mapping at the accuracy required in reservoir management practices. A scale of approximately 1:63,360 was determined to be the most useful because: 1) the maps prepared can be easily referred to 15-minute topographic quadrangles; and 2) at larger scales S190A photographs appear "grainy" and the scan lines in the ERTS-1 images become predominant, reducing the utility of the products.

Tonal characteristics of vegetative and agricultural units are more easily distinguished on color than on black and white imagery. Because of this, mapping on black and white prints is facilitated by periodic reference to the original color renditions. Also, when using ERTS-1 MSS imagery in preparing land use/vegetation maps, both bands 5 and 7 are required to distinguish water from forested and wetland areas.

The ground resolution of the satellite and aircraft data products was dependent upon the degree of tonal contrast between various features. As is generally found, linear features were more easily detectable than circular or oblate objects (Table II). Among the various types of imagery, as ground resolution improved, the number of mappable units (Table V) and mapping accuracy increased; this also is as expected.

Table V. Mappable land use/vegetation units.

	ERTS-1	*S190A*	*S190B*	*RB-57*
Level I	5+2 Combined	6	6	6
Level II	8	13	17	21
Level III	0	0	1	5
Total	15	19	24	32

CONCLUSIONS

It is evident from this comparison that for land use/vegetation mapping the S190B Skylab photography compares favorably with the RB-57 photography and is superior to the ERTS-1 imagery and Skylab S190A photography. For most purposes the 12.5-m width resolution of the S190B photography is sufficient to permit extraction of the information required for rapid land use and vegetation surveys necessary in the management of a reservoir or watershed. The ERTS-1 and S190A data products are not considered adequate for this purpose, although they are useful for rapid regional surveys at the level I category of the land use/vegetation classification system.