ETL-0175

Land cover classification from LANDSTAT data:

Phase III of a joint OCE/NASA demonstration

Richard N. Foreman

MARCH 1979

U.S. ARMY CORPS OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Corps of Engineers and NASA's Earth Resources Laboratory conducted a joint demonstration of the production of land cover classification data from LANDSAT data. This report describes Phase III of the demonstration, in which classification maps and data were produced for two Corps of Engineers Districts Wilmington District, an area in the upper Roanoke River basin of Virginia; and Jacksonville District, an area along the route of the Cross Florida Barge Canal The report includes the Districts' evaluations of the accuracy and applicability of the classifications and cost information for Phase III of the demonstration.

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The report also includes cost information for the application of interdisciplinary analysis of aerial photography as a means of obtaining land cover and environmental data.

LANDSAT data may be cost-effective for identifying and showing the distribution of general types of land cover for large areas, although some land cover types may not be identifiable on a particular LANDSAT scene. Interdisciplinary analysis of aerial photography identifies and explains in a technical report the distribution of land cover. The extra detail of the report and the ability to ensure that specific land cover types are studied may make interdisciplinary analysis of aerial photography cost-effective for limited study areas.

CONTENTS

I. PURPOSE OF REPORT

Since its launch in 1972, LANDSAT has been providing a great deal of information about the earth. The Corps of Engineers is one of many organizations which have investigated the application of this data to its operations. Part of the Corps' investigation has been a joint demonstration, with NASA's Earth Resources Laboratory (ERL), of the production of land cover classification maps from LANDSAT 1 and 2 data. In 1976 the New Orleans District evaluated a classification done by ERL of a portion of southern Louisiana and Mississippi. Although some problems were noted, the overall evaluation was favorable and it was suggested that system advances would improve the classification capability. (Ref. 1) To verify this, and to establish a broader base of experience upon which to assess the merits of the system, Phase III of the joint demonstration was expanded to include land cover classifications for two additional areas with differing terrain characteristics. This report forwards the evaluation of those classifications to the OCE Remote Sensing Committee.

II. LANDSAT SYSTEM

During the demonstration, land cover classifications have been made using data from a multispectral scanner aboard LANDSAT. The scanner measures reflectance in each of four wavelength bands and records it for picture elements or "pixels," each covering a 1.1 acre portion of the earth's surface. Although a full LANDSAT scene includes over 13,000 square miles, land cover classifications are prepared from the data for each 1.1 acre pixel.

The combination of four reflectance values recorded by the scanner for each pixel is unique for a given set of <u>spectral reflectance</u> conditions on the earth. Areas with similar <u>spectral reflectance characteristics</u> will record as similar intensity levels in the four bands. The combinations of reflectance values thus become signatures which can be used to identify and group areas predicted to have the same surface conditions. The groupings, once they have been labeled, become the land cover classification. ERL used this procedure in 1975 to classify approximately 24,000 square miles in southern Louisiana and Mississippi. The classification was displayed as color maps at a scale of 1:250,000 and combined in ERL Report No. 149. (Ref. 2) This is the classification evaluated by New Orleans District in 1976.

III. PHASE III, OCE/NASA JOINT DEMONSTRATION

Concept

As part of Phase III of the demonstration, land cover classifications were prepared for two areas with differing terrain characteristics. The areas chosen were a mountainous portion of the upper Roanoke River drainage basin within the Wilmington District and a relatively flat area along the route of the Cross Florida Barge Canal within the Jacksonville District. The classifications were prepared by ERL, with cooperation and input from district personnel. USAETL provided a program monitor for this phase to facilitate coordination between ERL, both Districts, and OCE. Work began on this phase of the demonstration in May 1977. Classification products were delivered to the Districts in December 1977 and January 1978.

Wilmington District

Area.

The Wilmington District is studying the 800 square mile headwaters area of the Roanoke River above Smith Mountain Lake. (Ill., III-1) A land cover classification of the study area was arranged with the Wilmington District as part of Phase III of the demonstration. Terrain in the area is rugged, with a variety of slope conditions and a number of micro-climate areas, providing a good test of the LANDSAT data classification system's capabilities.

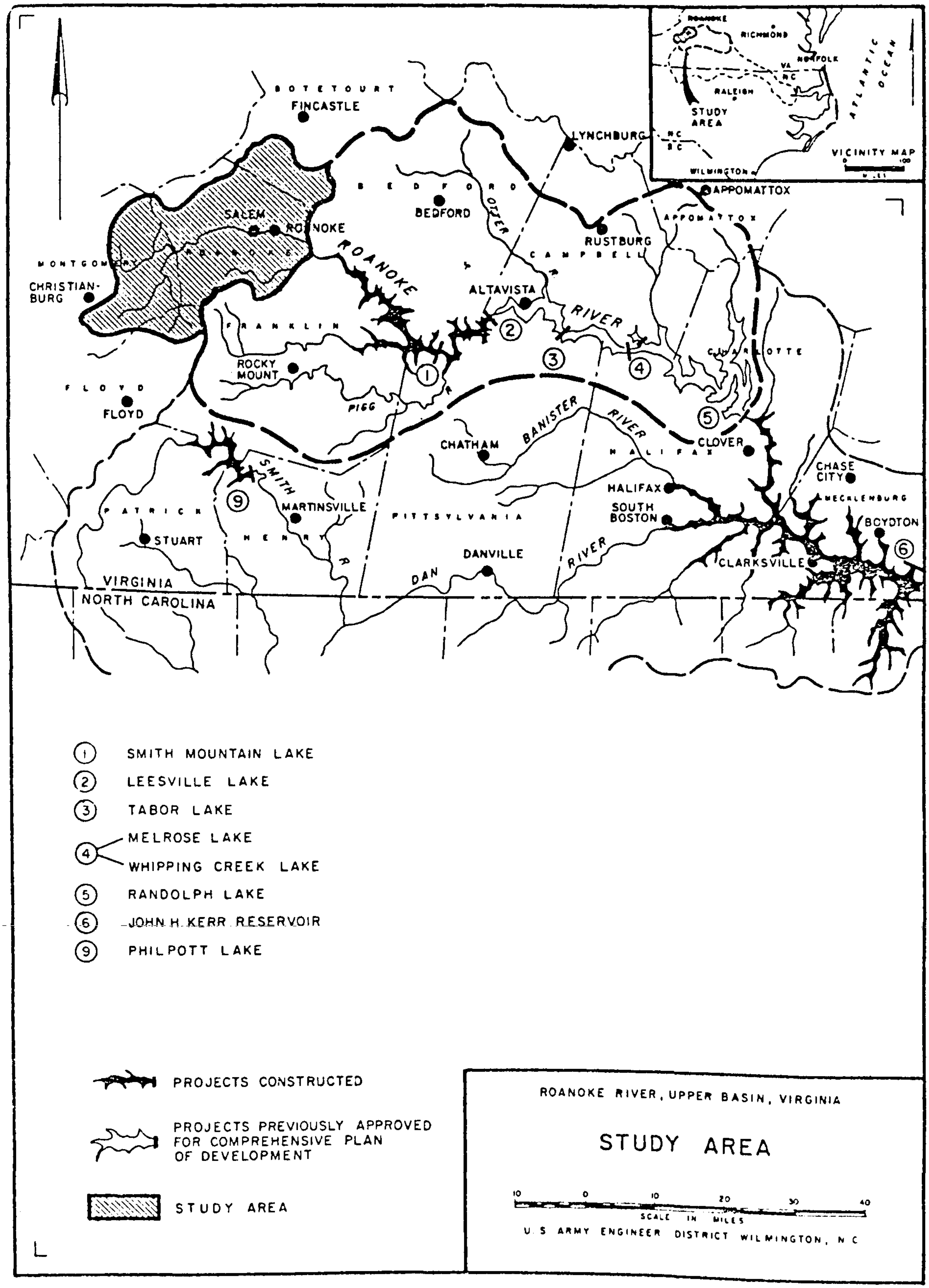


Illustration III-1

Technique

Wilmington's area was classified by applying a "supervised" computer sorting program to the LANDSAT data. The program, developed by ERL, relies upon ground truth sites (areas with known or pre-surveyed surface conditions) to provide input to classification processing. The ground truth sites are located on the LANDSAT scene and the multispectral signatures (described in Section II) for the sites are determined. A computer is "trained" on the signatures for these sites and it then makes maximum-likelihood calculations to identify the rest of the area. If ground truth sites are chosen with examples of the surface conditions the investigator is interested in, then the classification produced by the program will include those surface conditions. A more complete description of ERL's supervised program is provided by reference 3.

Application

Wilmington District's study is primarily to develop programs to overcome water supply and flood control problems in the area, but it will also address water quality, recreation potential, power generation, and overall environmental quality. The classification produced during the demonstration will be useful as input for the study. It will complement work which is being done on soils, slope, geology, land use, and other data variables. Land cover was classified in Level II and some Level III (species type of forest cover) categories as described in USGS Circular 671 (Ref. 4).

Evaluation

This section is based upon the evaluation prepared by Wilmington District. That evaluation is attached at Appendix A.

A field verification effort was designed to check the classification's accuracy, particularly in the types of forest cover shown. The other classes (types of urban and open land) can readily be verified from aerial photography.

Nine cells, each four square miles in size, were identified within the study area. Field teams visited these cells and compared the land cover shown on the classification to actual ground conditions. Accuracies of the different land cover classes are expressed as percentages in Table III-1.

Misclassifications between species and general type (oak/hardwood), white pine/pine) were common. By grouping classes, the overall accuracy of the classification was improved as shown in Table III-2. Information on these grouped classes is still useful and valuable to the District for understanding the environment within the basin.

Jacksonville District

Area.

The area done for the Jacksonville District is along the route

ACCURACY PERCENTAGES

TYPE		%
1.	Hardwood	72%
2.	Oak	67%
3.	Pine	91%
4.	White Pine	17%
5.	Mixed	91%
6.	Residential	82%
7.	Commercial/ Industrial/ Institutional	83%
8.	Cropland	-
9.	Grassland	100%
10.	Barren (Only 2 sites checked)	100%

TABLE III-1

COMBINED CLASS ACCURACY		
1.	Hardwoods/Oak	89%
2.	Pine/White Pine	90%
3.	Mixed (Pine/Hdwd)	91%
4.	Residential	82%
5.	Commercial/Industrial/ Institutional	83%
6.	Cropland	-
7.	Grassland	100%
8.	Barren	100%

TABLE III-2

of the Cross Florida Barge Canal. (Ill. III-2) The relatively flat terrain contrasts sharply with the mountainous terrain of the Wilmington District area and it provided a good measure of the LANDSAT data classification system's performance under the different conditions.

Technique

The area for Jacksonville was classified with an "unsupervised" computer classifying program developed by ERL. This program, Program SEARCH, screens data for a LANDSAT scene and automatically identifies the significantly separable multispectral signatures for homogeneous areas within the data. These signatures are then used to classify the entire scene, based on information obtained by ground truth examination similar to the ground truth step of the "supervised" program. It is up to the investigator to compare computer extracted homogeneous areas with surface conditions and to identify those separable signatures recognized by the computer. The land cover classes can then be labeled. Appendix B provides additional information about Program SEARCH.

Application

The land cover classification produced will not be immediately applied to an active project, since construction of the Cross Florida Barge Canal was halted in 1971. The Corps of Engineers was made lead agency for preparing a restudy report and environmental statement about the project in 1974. The LANDSAT classification identified land cover

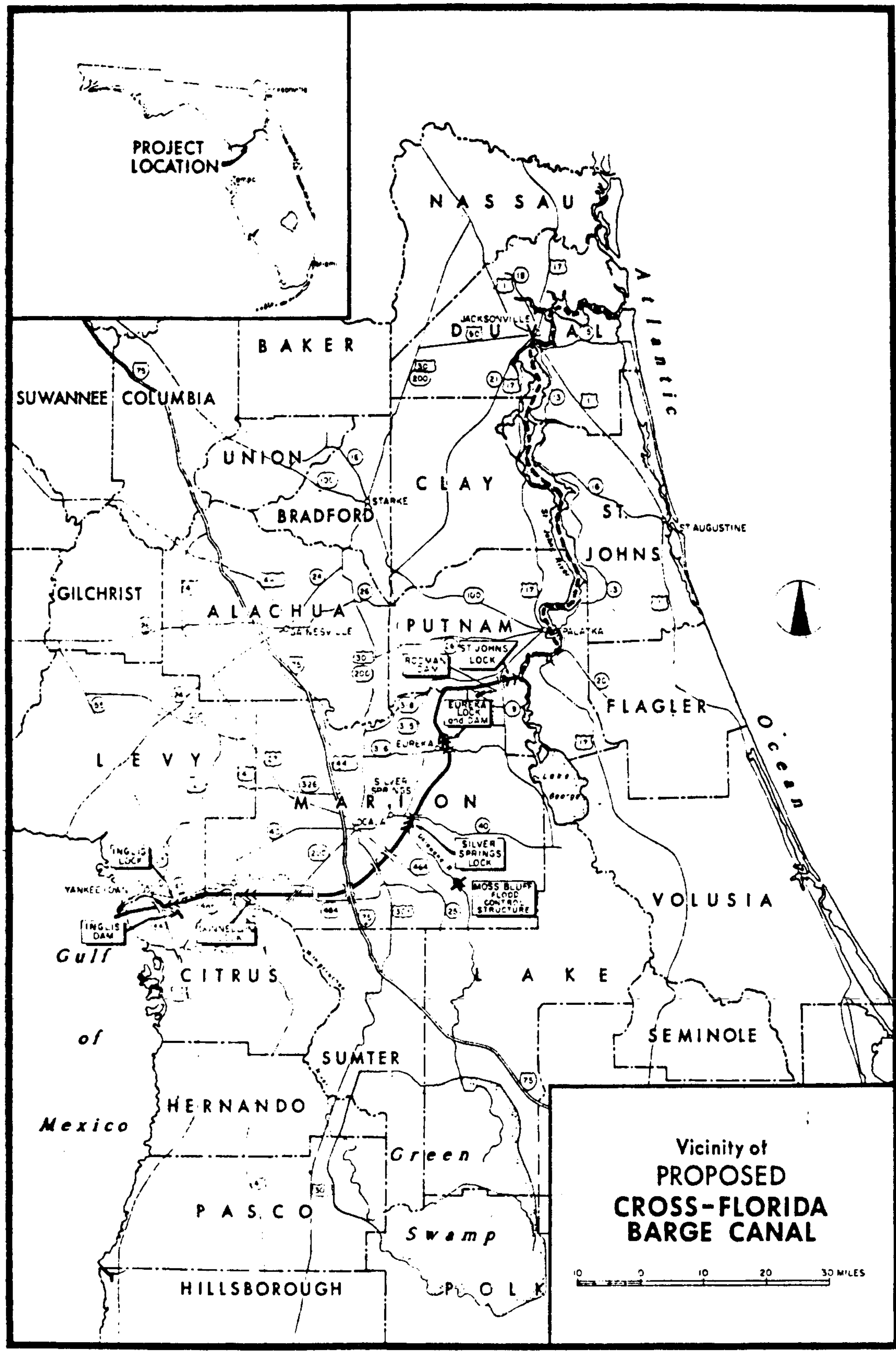


Illustration III-2

in Level II and several Level III or finer (species and character of vegetation) categories as described in USGS Circular 671 (Ref. 4).

Evaluation

This section is based upon the evaluation prepared by Jacksonville District. That evaluation is attached at Appendix C.

In support of the restudy effort, the Forest Service prepared a vegetation study of a corridor along the canal route in 1976. The study provided an inventory of vegetation and made predictions of ecological impacts associated with the canal project. The Forest Service's study and the LANDSAT classification involved different techniques of operation, and the personnel making each study had different backgrounds and levels of expertise. This makes a detailed evaluation of the two efforts difficult, but several comparisons can be made.

The Forest Service study included 166,391 acres, of which 50,176 were within a corridor along the authorized canal route. The LANDSAT classification included 324,087 acres (500 square miles) along the canal route. An additional 1.8 million acres were classified and displayed graphically, but no statistics were developed for this extra area.

The surface conditions classified in both the Forest Service and the LANDSAT studies may be grouped into three categories: Water, Non-Forest, and Forest. The classifications represent different types, or varieties, within these categories. With the exception of Forest, the LANDSAT and Forest Service studies identified a similar number of distinct classifications within each category. The differences in techniques and personnel were particularly apparent when attempts were made to directly correlate the forest classifications made in each study. They could not be correlated, making a firm evaluation of the LANDSAT system's accuracy against the Forest Service study inappropriate. However, a general review of the classifications from the LANDSAT system and of their locations indicates that land cover within the Cross Florida Barge Canal project area was adequately grouped and classified. The LANDSAT classification would have been suitable for planning the Cross Florida Barge Canal project.

The Forest Service study took thirteen months to complete. The LANDSAT classification was done in eight months. Without information available from the Forest Service study, the LANDSAT classification probably would have required ten months.

The Forest Service study cost $207,000 [and included predictions of the ecological impacts associated with canal construction. The LANDSAT classification cost approximately $18,592.]

The LANDSAT land cover classification technique does not reduce field study time and manpower requirements. It does reduce the effort required for land cover cartographics and acreage determination.

IV. COST

Demonstration Cost

NASA (ERL) and OCE spent approximately $56,532 to produce the two study area classifications in Phase III of the demonstration. An exact cost for each area is not available because many activities were done simultaneously or in support of both areas, making it impractical to keep separate records for each. In developing a cost for each area, the different classification techniques used make it improper to simply split the total cost in half. It was necessary to determine the effort actually expended on each area by ERL and by OCE. Good estimates are available of the ERL Civil Service and OCE costs for each area, but the largest single expense was for ERL's in-house contractor support. This cost, $32,666, is based on the direct labor man-hours spent by the contractor, but also includes the contractor's profit and ERL's maintenance and operating overhead. An estimate was made of the direct labor man-hours spent on each study area and the contractor cost distributed accordingly. The total cost of $56,532 divides into $40,069 for Wilmington and $16,463 for Jacksonville. More information on cost determination is at Appendix D.

There were a number of expenses during the demonstration which would not be incurred within a continuing production program. There was extra coordination within the Corps of Engineers, and ERL adjusted computer programs and tried new techniques in order to make the final classification and products best meet the desires of Jacksonville and Wilmington Districts. This effort would be minimized in a cost effective production program with established specifications and standardized techniques, but it was not limited during the demonstration. An allowance can also be made for classification materials retained by ERL and for programming and processing techniques developed during the demonstration which are applicable to other ERL projects. ERL estimates that fifty direct labor man-hours, or $1,500, were involved in these efforts.

Alternate Technique

It is difficult to identify a standard cost for a current alternate technique. Techniques used for developing land cover data are selected by each District and may change within a District based upon the requirements of each project. One technique for which performance specifications and cost data are available is the interdisciplinary analysis of aerial photography.

Interdisciplinary analysis of aerial photography was used in five Corps of Engineers demonstration projects in 1975 and 1976. In each project, land cover was classified at Level II, as described in USGS Circular 671 (Ref. 4). A great deal of Level III information (detailed descriptions of urban or built-up land cover and species type of forest cover) was also available and was used by the teams in their analyses. Project participants were able to study specific land cover types of particular interest. Verification of the classifications established that land cover was identified in the demonstration projects with 90% or greater accuracy. A technical report describing the environment and land cover in the study area and discussing the interaction of environmental factors was prepared during each project. Each report explained how the factors had combined to create the present environment in the study area and provided a basis for predicting the impact if any of the environmental factors were altered.

Detailed information available for one of the demonstration projects shows that the land cover information and technical reports were generated for approximately $79 per square mile. It should also be noted that the $79 per square mile cost for the demonstration project included training for the project participants. If people already familiar with interdisciplinary analysis techniques are available, the cost of a study can be considerably reduced. Each demonstration project was completed within five weeks.

~~Interdisciplinary analysis is also available from private~~ contractors. Recent experience in one District suggests that limited analysis is available for less than $50 per square mile. Environmental factor mapping was done for a 1,000 square mile watershed for $47 per square mile. The study area was quite complex, including mountains and heavily urbanized areas, but factor mapping was done at levels comparable to Level II, as described in USGS Circular 671 (Ref. 4). More detailed mapping of soil types and terrain features was also done and a technical report describing the factors mapped was prepared. The $47 per square mile did not include interpretation of the mapped data and application of it to the District's floodwater control and water supply problems, nor did it include training for District personnel. An additional phase of the contract did provide the interpretation and application of the mapped data, but the effort required to interpret and apply environmental data depends very heavily upon the characteristics of a study area and upon the nature of the problem being addressed. It is inappropriate to reduce costs for this effort to a price per square mile.

V. SUMMARY

General

Phase III of the joint Corps of Engineers/NASA ERL demonstration of land cover mapping from LANDSAT 1 and 2 data included the preparation of land cover classifications for two areas; one within Jacksonville District, and the other within Wilmington District. The areas had differing terrain characteristics. The classifications were prepared by different computer processing techniques.

Accuracy

Jacksonville District's study area was related to the Cross Florida Barge Canal project. The LANDSAT classification of land cover was adequate for the objectives of their study of that project. Wilmington District found that the LANDSAT classification identified land cover types with an average accuracy of 78%. Grouping of some types increased the accuracy to 90%. Land cover for both areas was identified in Level II and some Level III categories as described in USGS Circular 671.

Applicability

Jacksonville and Wilmington Districts both felt that the classifications from this demonstration support their current efforts. Jacksonville District feels that LANDSAT techniques could be applied to other projects; Wilmington District suggests further study to determine the optimum value of LANDSAT mapping.

Timeliness

Classification products for both study areas were completed within eight months.

Cost

The classification for Jacksonville District cost approximately $16,463, or $33 per square mile. The classification for Wilmington District cost approximately $40,069, or $50 per square mile. Information about the cost of LANDSAT classifications on a production basis is at Appendix E.

Alternate Technique

Interdisciplinary analysis of aerial photography provides land cover information at Level II and Level III classifications for approximately $80 per square mile. This technique also provides a technical report describing the interaction of land cover and other environmental factors. A typical analysis can be completed within five weeks, including training. Land cover mapping, without the training or the technical report, is available commercially for $50 per square mile.

Conclusions

LANDSAT techniques appear to be cost effective for identifying and showing the distribution of general types of land cover for large areas. It should be noted however, that some land cover types may not be identifiable on a particular LANDSAT scene. The unidentifiable land cover types may vary from region to region and with the seasons.

Interdisciplinary analysis of aerial photography identifies and explains in a technical report the distribution of land cover. The extra detail of the report and the ability to ensure that specific land cover types are studied may make interdisciplinary analysis of aerial photography cost effective for limited study areas. Cost effectiveness would have to be determined based on the actual requirements of a particular project.

Recommendations

It is recommended that:

a. Corps elements consider using LANDSAT data for meeting their needs for general land cover information for large areas.

b. Corps elements contract the processing of LANDSAT data as required.

VI. REFERENCES

1. Letter, LMNPL-F to DAEN-CWP-S, subject: Evaluation of South Louisiana Remote Sensing Project, 17 February 1976. (Attached)

2. Anon.: LANDSAT Satellite Computer Derived Environmental Maps, South Louisiana. ERL Report No. 149

3. Whitley, Sidney L.: A Procedure for Automated Land Use Mapping Using Remotely Sensed Multispectral Scanner Data. NASA TR R-434, January 1975

4. Anderson, James R., et al.: A Land-Use Classification System for Use with Remote-Sensor Data. Geological Survey Circular 671, 1972

Reference 1

LMNPL-F

17 February 1976

SUBJECT: Evaluation of South Louisiana Remote Sensing Project

THRU: Division Engineer, Lower Mississippi Valley
ATTN: LMVPD-F

TO: HQDA (DAEN-CWP-S/Mr. Penick)
WASH DC 20314

1. The Phase II demonstration product for the South Louisiana Remote Sensing Project was delivered to the New Orleans District in June 1975. The project is a joint venture being conducted by the US Army Corps of Engineers and the Earth Resources Laboratory; and the Phase II demonstration product is an atlas made up of simulated color infrared photo maps and computer derived land use classification maps.

2. The primary objective of the evaluation of the Phase II product was to determine the accuracy of the computer derived land use classification maps. A comparison of available information was undertaken to evaluate the land use maps. Three general areas were chosen from the south Louisiana area: the Baton Rouge Metropolitan area (area 1), the Houma area (area 2), and the New Iberia area (area 3). Each area measured approximately 14 miles by 40 miles and represented 563 square miles of surface area. The latter two areas were chosen because they present a diversity in land features and foliage. The former area was chosen because it is a medium-size metropolitan area.

3. The comparison documents used were 1:62,500 scale high level infrared aerial photographs. Photo interpretation was performed on the infrared photographs; blackline overlays were made for the previously mentioned evaluation areas; and the following land use categories were noted:

Urban Buildup

Agricultural Land

Wetlands

Forested Wetland

Forest Land

Water

4. The overlays were superimposed upon the derived land use maps and the following percentages of agreement were observed:

	Area 1	Area 2	Area 3
Agricultural land	90%+	90%+	90%+
Wetland	90%+	90%+	90%+
Forest Land	90%+	90%+	90%+
Water	90%+	90%+	90%+
Forested wetland	Not distinguishable from forest without ground truthing		
Urban buildup	60%+	70%+	80%+

Inspection of the figures presented above indicates a high rate of proficiency in distinguishing agricultural land, wetland, waterbottom, and forest land. Forested wetland was discernable on the high level infrared photographs, however, a distinct line of demarcation was not readily observed, therefore, that category was not evaluated.

5. Areas which were visibly urban to the naked eye were able to confuse the multispectral scanner. The overlays revealed that while the computer had the ability to recognize components of the urban grouping, city parks and older, grownup neighborhoods appeared to be forest land, and playgrounds and golf courses were interpreted as being agricultural land, thereby accounting for the relatively low degree of accuracy for urban areas.

6. At present, the system is generally efficient in differentiating land use types. With further development it is expected that more detailed breakdowns within the general categories presently used can be accomplished. It would be possible to distinguish fresh marsh from brackish or intermediate marsh, and soybean fields from rice fields or sugar cane fields. Additionally, by using supplemental information and further refining of the system, it is expected that urban areas can be more clearly delineated. On the basis of recent results and expected advancement, the system is recommended for implementation.

EARLY J. RUSH III
Colonel, CE
District Engineer

APPENDIX A

Wilmington District Evaluation

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402

IN REPLY REFER TO

SAWEN-E 17 May 1978

SUBJECT: Evaluation of Upper Roanoke River Basin ASVT

ETL-RSC/CAPT Richard N. Foreman
U.S. Army Engineer Topographic Laboratories
Fort Belvoir, VA 22060

The subject evaluation is inclosed as requested in ETL-RSC letter dated 14 November 1977, addressed to Mr. Coleman Long of this office.

FOR THE DISTRICT ENGINEER:

E. G. Long, Jr.

1 Incl
as

E. G. LONG, JR.
Chief, Engineering Division

CF w/incl:
SADEN-FG

EVALUATION OF UPPER ROANOKE RIVER BASIN ASVT

1. In the Wilmington District's survey scope study of the Upper Roanoke River Basin (URRB) in Virginia, we faced the problem of obtaining a general vegetation map for an 800-square-mile area. Little or no existing mapping was available. As we were considering various remote sensing techniques, we were offered an opportunity to test the usability of LANDSAT imagery in the mapping of land-cover classes in the URRB. This was done as a part of the technology transfer program of NASA's Earth Resources Laboratory in Slidell, Louisiana. The services of the Corps of Engineers Topography Laboratory were also important in the effort. NASA produced a land cover map for the URRB by computer interpretation of LANDSAT scenes from 16 April 1976. The classes mapped include:

(1) Hardwoods (mixed hardwoods)
(2) Oak
(3) Pine (all except white pine)
(4) White pine
(5) Mixed pine/hardwood
(6) Grassland
(7) Cropland
(8) Residential
(9) Commercial/Industrial
(10) Barren (exposed earth - construction sites)
(11) Water

2. Verification. The land-cover mapping will be used with other data variables such as soils, slope, geology, and land use to study land suitability, land vulnerability and impacts of alternative plans. Since the use of LANDSAT imagery for land-cover mapping is relatively new and untested, we felt it necessary to field verify the results. Additionally, because of the nature of LANDSAT we feel the classification accuracy of any LANDSAT product should appear on the map, preferably in the form of the "confusion matrix."

3. Verification Design

Our primary concern during field investigation was the accuracy of the mapping for the forest types: mixed hardwood, oak, pine, and white pine. The urban classes and cleared lands are easily identified from aerial photography so that no real intensive field effort was necessary. We were also interested in accuracy differencesat various elevations and locational accuracy of LANDSAT mapping to cultural base maps.

We stratified the basin into three major areas to represent elevation and development differences: lower elevations of the urbanized valley (Salem, Roanoke, and Vinton); North Fork Province; and South Fork Province. Three 2-mile by 2-mile cells were then randomly selected within each province. The four square-mile area was selected as the cell size for ease of access, coverage, and identification on aerial photography. We felt that a two-man team, on foot, with aerial photography could easily cover one cell a day as a minimum.

The color-coded classes of the LANDSAT map within each cell were located on aerial photographs of the same areas and labeled as to its LANDSAT classification. Only those mapped areas of approximately 10 acres or greater were transferred to the aerial photography. We felt that any mapping of areas less than 10 acres in size would lead to increased field time to determine location and would be most susceptible to transition errors. Each cell was then positioned on 1:24,000 quad sheets for field location.

4. Field Verification

The actual fieldwork was performed by two teams, consisting of two men working over a one-week period. The cells were checked by locating each area identified on the aerial photograph in the field and recording its "true" classification. Each four square-mile area yielded approximately 5-8 sites for each class (forest type), except white pine and mixed pine/hardwood. Both of these classes proved to be scarce throughout the basin and would not submit to random selection. These classes were therefore observed specifically.

Results of the field investigation are listed below in a matrix showing LANDSAT class versus "true" class as ground checked.

TABLE 1

GROUND VERIFICATION

LANDSAT CLASSES	[TOTAL SITES]	HARDWOOD	OAK	PINE	WHITE PINE	MIXED	RESID.	COMM/IND INST.	CROPLAND	GRASS.	BARREN
Hardwood	47	34	9	1		2		1			
Oak	36	7	24	2		1				2	
Pine	44	2	1	40		1					
White Pine	6			4	1	1					
Mixed (Pine-Hdwd.)	11		1			10					
Residential	56	1	2	1		3	46			3	
Commercial Industrial Institutes	24	1	1				2	20			
Cropland		THIS CATEGORY WAS NOT VERIFIED BECAUSE TIME OF YEAR PROHIBITED. FEB/1978									
Grassland	40									40	
Barren	2	ONLY TWO SITES CHECKED FOR THIS CLASS									2

5. Accuracy Results

Table 2 presents the accuracy of percentages based on number of "true" sites (field class matched LANDSAT class) versus total number of sites checked for each class. Each site checked was recorded under its real class to identify where errors were occurring.

Of the 47 hardwood sites checked, 34 were "true" sites while the remaining 13 were divided into 9 oak sites, 1 pine site, 2 mixed sites, and 1 urban site. The majority of the misclassifications was to the oak class.

Twenty-four of the 36 oak sites checked were "true" sites, while the majority of the misclasses (7) was to the mixed hardwoods. Although we do not have enough sites within each elevation for statistical proof, the oak class seemed to record more accurately at the higher elevations.

The pine class mapped very accurately, with 40 out of 44 sites checked as "true" sites. Errors were randomly distributed.

Only 6 white pine sites were identified for field verification. The white pine class was extremely sparse throughout the basin with only an occasional site of 5- to 10-acre size. Of the 6 sites checked, only one was a true site with four of the five misclasses going to pine.

Very few large (10 acres +) sites of mixed pine/hardwoods were mapped. Of the 10 sites checked, all 10 were "true" sites.

The urban classes were more difficult to verify because of the locational inaccuracies and the transition of classes. Of the 56 residential sites checked, 46 were "true" sites. The misclasses were well distributed among the other classes.

Small residential classes (less than 10 acres) in rural and heavily forested areas proved to be extremely inaccurate, with less than 50% "true" sites. In the urban areas of Roanoke and Salem, where residential patterns were more distinct and tracts were larger, the mapping was very accurate. The same held true for commercial/industrial areas with a 20 out of 24 accuracy level.

In the agricultural categories of cropland and grassland, time of year prohibited a true test of accuracy. If we used "open" land as a general classification, we found a 100% accuracy level on the 40 sites checked.

Because of the scarcity of barren sites identified from the LANDSAT image, only 2 areas were verified. Both were "true" sites.

6. <u>Changes</u>. In order to improve the accuracy of mapping for use in our data base, we decided to combine several classes. Table 3 presents the accuracy percentages if oak and mixed hardwood are combined and if pine and white pine are combined. Both new classes have accuracy levels of 90% (approx.). See table 3.

7. <u>Summary</u>

We believe that, with a few adjustments in class types, LANDSAT mapping for the Upper Roanoke River Basin will be extremely valuable to our understanding of the environmental quality of the basin. The ability to combine land cover information from LANDSAT imagery with other data variables to predict suitabilities and impact is yet untested but appears fruitful.

Since our use of the LANDSAT imagery is for general basin-level land cover mapping, our verification efforts have focused on a general description of accuracy. More statistical verification efforts will be necessary to determine the optimum value of LANDSAT mapping and its final level of usefulness.

ACCURACY PERCENTAGES

TABLE 2

TYPE	%
1. Hardwood	72%
2. Oak	67%
3. Pine	91%
4. White Pine	17%
5. Mixed	91%
6. Residential	82%
7. Commercial/ Industrial/ Institutional	83%
8. Cropland	-
9. Grassland	100%
10. Barren (Only 2 sites checked)	100%

TABLE 3

COMBINED CLASS ACCURACY	
1. Hardwoods/Oak	89%
2. Pine/White Pine	90%
3. Mixed (Pine/Hdwd)	91%
4. Residential	82%
5. Commercial/Industrial/ Institutional	83%
6. Cropland	-
7. Grassland	100%
8. Barren	100%

APPENDIX B

<u>Program</u> <u>SEARCH</u>

NASA/ERL provided descriptive material on Program SEARCH. That material, with deletions as noted, is reproduced in the following pages.

PROGRAM SEARCH - VERSION II

I. PROGRAM DESCRIPTION

A. Abstract/Purpose

Program SEARCH is an unsupervised trainer for a maximum likelihood classifier.

SEARCH is an unsupervised approach different from other unsupervised approaches. The key differences are:

1. SEARCH evaluates blocks of data and only uses those blocks that appear homogeneous. This minimizes mixed pixel interference in computing stats and insures a degree of spatial integrity of the statistics.
2. Since a covariance matrix is computed on each block, the correlation in the data can be used in determining which stats are to be merged if the divergence separability measure is used.
3. SEARCH can obtain statistics for an entire Landsat frame in an hour to an hour and one-half if the large block size is used and in two to two and one-half hours if the small block size is used. (Time required is data dependent--time given is Varian 75 run time, approximately $55 per hour.)

Program SEARCH as is now coded operates exclusively on four-channel data. There are no theoretical considerations limiting the procedure to four-space; however, the program was developed primarily to process Landsat data.

B. Interfaces

1. Input

a. Reformatted tape (four-channel only).

b. Terminal (input options).

2. Output

a. Stat file (same format as output by CVIPS).

b. Terminal (output listing) - See Attachment II.

C. Responsible Programmer

Ronnie Pearson
NASA/ERL
Slidell, LA

II. DETAILED DESCRIPTION

A. Technique

See IV.A - USERS OPTIONS before reading.

SEARCH evaluates each contiguous six scan line by six element block of input data for use as a training field. The six scans taken in one swath by the Landsat satellite are evaluated at the same time by SEARCH. Each six scan by six element block of data is used for a training field if the standard deviation in each channel is in the interval from SDLB (standard deviation lower bound) to the maximum of SDUB (standard deviation upper bound) and COV (coefficient of variation/100) times the mean of the particular channel being tested. If the small area option is on, the four three scan line by three element blocks of data within the six by six block are evaluated for use as a training field if the larger block is not found useable. The statistics for each field found useable are held in memory. Once fifty sets of statistics, i.e., means and covariance matrices, have been stored, the pair of statistics with the smallest separability measure is merged. This merger allows the fiftieth slot to once again be vacant and used for the storing of statistics of the next field found suitable for use as a training field. This alternating field selection and statistics merging continues then through all the input data desired. If at any time during the running of SEARCH the smallest separability measure is greater than DVM (desired maximum separability measure for merger), then all individual field statistics not having a divergence of 4.5 times DVM with some set of statistics derived from two or more fields are dumped. If, in this situation, no statistics are dumped, then DVM is incremented. To date no Landsat data set has forced the incrementation of DVM when the small area option was off.

After processing all the desired input data, SEARCH merges the pair of statistics having the smallest separability measure, provided this value is not greater than DVM. This merger process is done reiteratively until the minimum separability measure exceeds DVM.

To avoid classifying many small and usually rather insignificant classes, SEARCH deletes all the sets of statistics derived from 4, 3, 2, or 1 field(s) not having a separability measure of 1.5, 2.5, 3.5, or 4.5 times DVM, respectively, with each set of statistics derived from that many or more fields.

The remaining sets of statistics are printed out and an 8100 type stat file, less histograms, is written to disc.

II.B Mathematics (deleted)

III. HARDWARE REQUIREMENTS

A. Machine - V-70 Series Computer

B. Storage - 27K Decimal

C. Peripheral Devices - 1 Tape, 1 Terminal, 1 RMD

IV. PROGRAM USERS INFORMATION

A. Options

1. Amount of data to be input.
2. Start and stop scan lines and elements for each area/tape.
3. Window size and separability measure selector - Pairwise divergence or scaled distance can be used. The scaled distance used is determined by multiplying a candidate merged mean by COV. If this value is less than one it is set to one yielding euclidean distance.
4. DVM - Maximum desired separability for merger.
5. SDLB - Standard deviation lower bound.
6. SDUB - Standard deviation upper bound.
7. COV - Coefficient of variation/100.
8. Status Check - Attained by keying RUBOUT. This causes location and statistics for last field accepted to be printed out. The following inputs then cause processing to continue in the indicated manner.
   a. 0 (or no entry) - continue after forming histograms.
   b. 9 - continue.
   c. 4 - accept no more input data.

B. Restrictions

1. ERL reformatted input with four data channels.
2. Forty-nine classes are the resident maximum in core; therefore, forty-nine classes are the maximum obtainable.

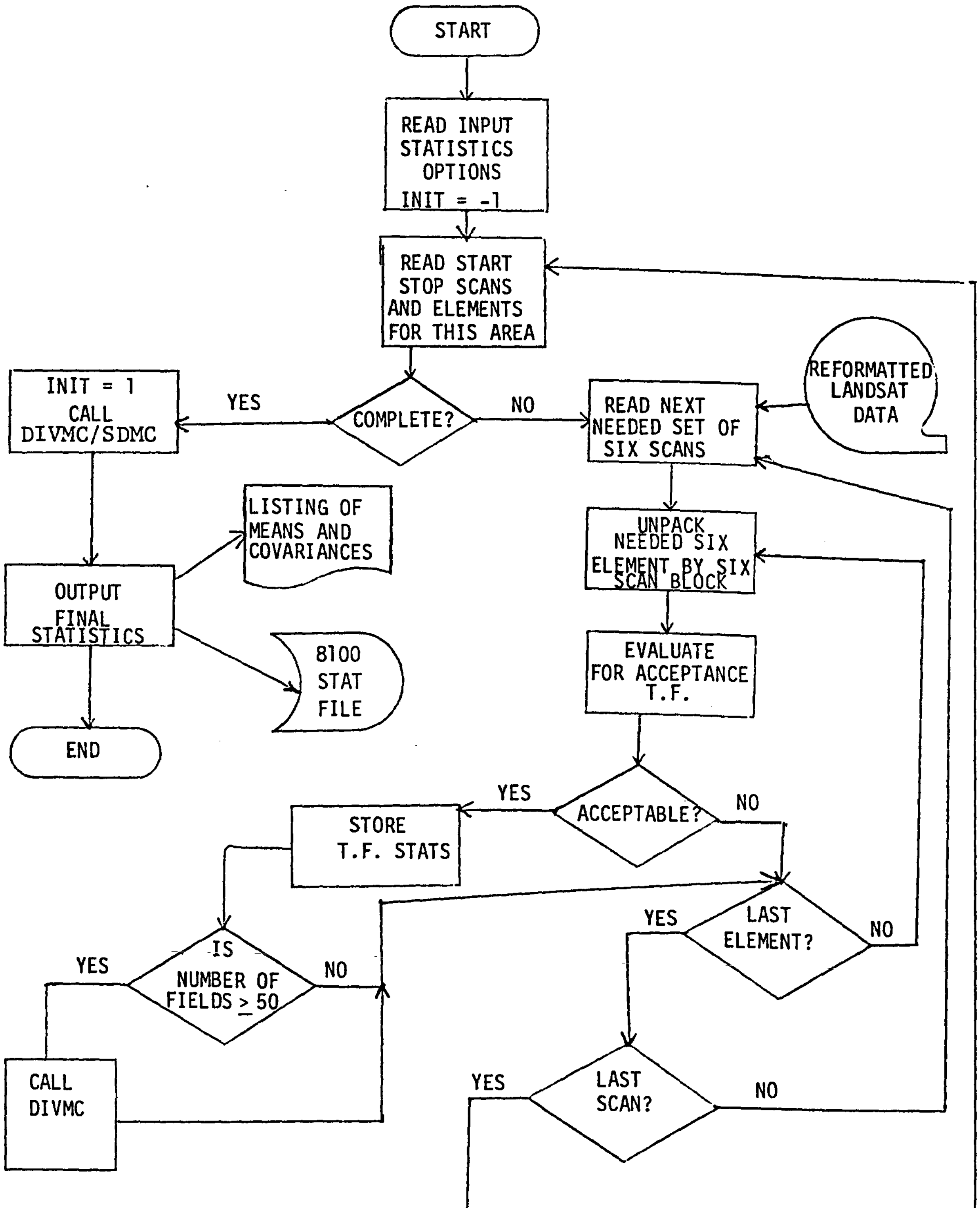
C. Non-Standard System Subroutines

None.

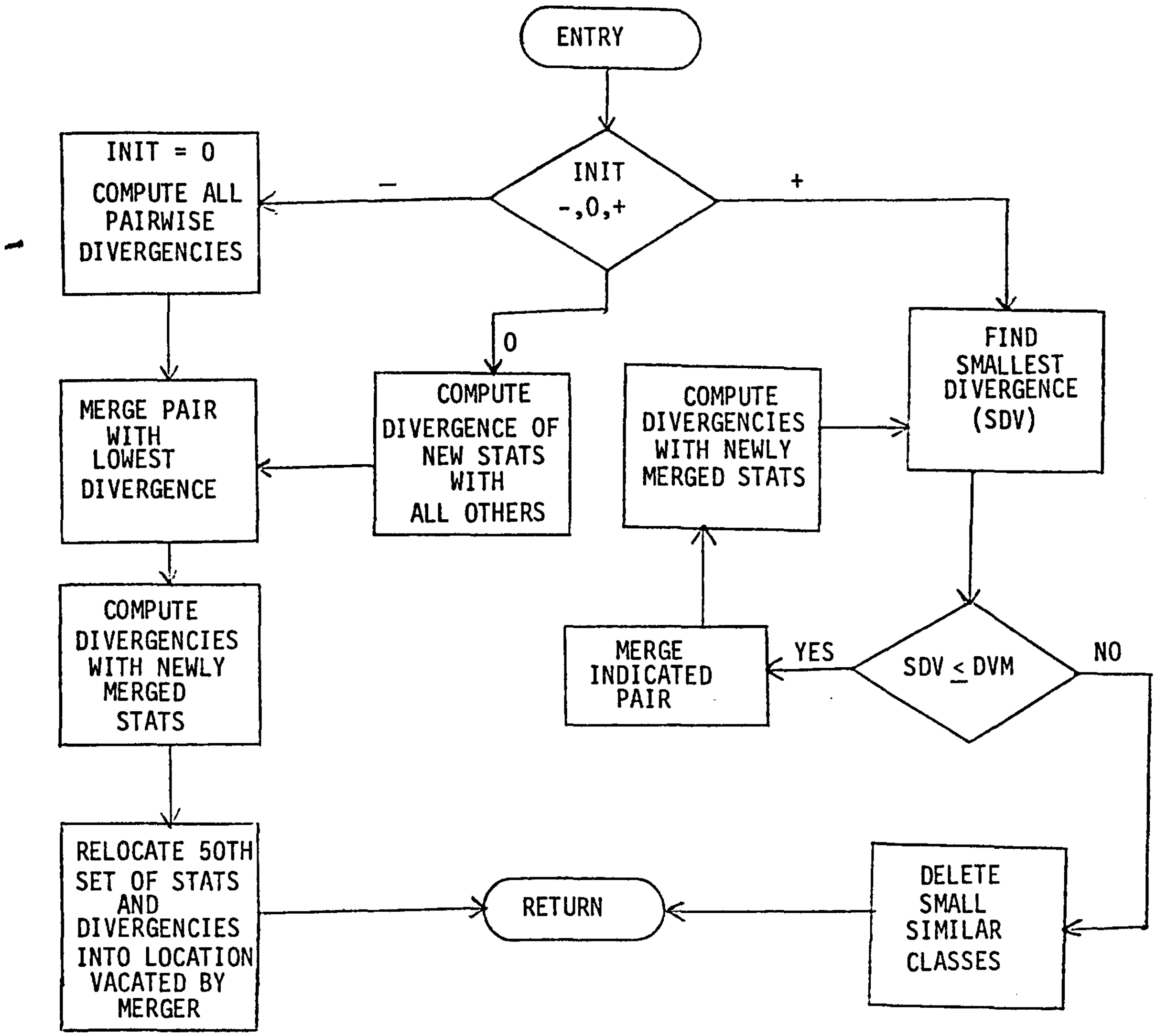
V. DECK SETUP (deleted)

VI. FLOW CHART

A. SEARCH (Main Program)



B. DIVMC



C. SDMC

Identical to DIVMC except scaled distances are used rather than pairwise divergencies.

VII. PROGRAM LISTING (deleted)

Attachment I SEARCH SUBROUTINES (deleted)

Attachment II (deleted)

APPENDIX C

Jacksonville District Evaluation

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 4970
JACKSONVILLE, FLORIDA 32201

SAJEN-EE 28 March 1978

SUBJECT: Corps of Engineers-NASA Applications System Verification and Transfer (ASVT) Evaluation

Commander and Director
United States Army Engineer
Topograghic Laboratories
ATTN: ETL-RSC R&D Coordinator
Ft. Belvoir, VA 22060

1. Reference ETL-RSC letter dated 14 November 1977.

2. Subject report is attached.

FOR THE DISTRICT ENGINEER:

George Marsch

1 Incl
AS

GEORGE MARSCH
Acting Chief, Engineering Division

CORPS OF ENGINEERS - NASA APPLICATIONS SYSTEM VERIFICATION AND TRANSFER (ASVT) EVALUATION

1. Differences between LANDSAT-acquired data and hand-calculated and mapped data on the Cross Florida Barge Canal Study (CFBC) are summarized as follows:

	NUMBER OF CLASSIFICATIONS	
Classification Categories	CFBC	LANDSAT
Water	6*	5
Non-Forest	10**	11
Forest	18	10
TOTAL	34	26

* Natural lakes and ponds are distinguished from reservoirs.
** Railroad right-of-way is distinguished from highway right-of-way.

2. The CFBC study distinguished eight different classifications of pine forest, six pine flatwoods, four classifications of hammock, and five classifications of swamps and bayheads, based on canopy alone. Based on canopy and understory studies, three types of pine flatwoods were distinguished, five different pine habitats, and five hammock habitats. Only 16 different forest classifications were made on the basis of canopy-plus-understory. LANDSAT showed at least three different signatures for pine forest; perhaps one or two others could have been so classified. Perhaps three hammock classifications were possible with the LANDSAT system. Uncertainty in the comparison of the two systems stems from using people with different levels of expertise and background, who used different techniques in operation of the two systems.

3. Subparagraphs below correspond to those of ETL-RSC letter, 14 November 1977.

a. For the purposes of the CFBC original study objectives, the LANDSAT technique adequately grouped and classified land cover classes.

b. The LANDSAT product would have fulfilled the requirements for planning the CFBC project. Other projects which require that extensive areas of land cover be mapped could profitably be approached with LANDSAT techniques.

c. The time required for the LANDSAT product was eight months, including a time lapse to obtain photographs. Total time for the CFBC study was 13 months. We believe that without information from the CFBC study, perhaps two more months would have been added to the LANDSAT study.

d. The cost of the CFBC study was $207,000. We do not have cost figures for the LANDSAT system.

e. No changes in the LANDSAT approach are envisioned.

f. General.

(1) Some time was spent exploring and deciding on Program SEARCH, and there was time spent strictly in familiarization and instruction. These time periods would be reduced later.

(2) The LANDSAT product was well worth the effort. The decision on whether to use the system would turn not on manpower, but on hardware, software, and system operations costs.

4. The Jacksonville District approached the ASVT exercise with the purpose of comparing manpower and cost requirements with conventional methods. One question we had was whether man-time in the field, with its attendant mobilization and hardware requirements, could be reduced by use of LANDSAT technique. The answer is that field study time and manpower cannot be reduced by LANDSAT technique, but desk time, calculating acreages, drafting, and coloring maps, can be reduced and the final product improved by LANDSAT technique.

DEPARTMENT OF THE ARMY
UNITED STATES ARMY ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

ETL-RSC

14 November 1977

Mr. Gerald Atmar
U.S. Army Engineer District, Jacksonville
ATTN: SAJEN-E
P.O. Box 4970
Jacksonville, FL 32201

Dear Mr. Atmar:

ERL has estimated that the Jacksonville product of the ASVT will be ready by the end of November 1977. The graphic product will be forwarded for your evaluation and use.

One purpose of the ASVT is to decide whether or not the Corps should develop this application of LANDSAT data into a standard technique available for civil works projects, and your evaluation of the material being prepared by ERL will be a major factor in making that decision. The overall ASVT evaluation will be based on information provided by you, Wilmington District, ERL, and the ETL program monitor. The evaluation will address the involvement required of each agency as well as the quality of the LANDSAT product. It will help in assembling that evaluation if your input includes the following considerations:

a. Accuracy - Are land cover classes correctly grouped? Are the classes correctly identified?

b. Applicability - Would this product have been useful in planning the cross-Florida Barge Canal? Are there other projects for which this or a similar product would be useful?

c. Timeliness - If the product had been requested in support of an active project, would the time required to prepare it have been acceptable?

d. Cost - What has it cost you to get similar information from other sources?

e. Changes - What would you like to have done differently? Are there techniques which you feel should or should not have been used? Were any portions of the study under or over emphasized? How would the procedural changes affect the data shown on the product?

f. General

(1) Since this was a test of a new program, some effort was spent for familiarization with the system and experimentation to select approaches and procedures. Can you identify some of this effort and describe how it would be reduced in a continuing program?

(2) All things considered, is the product generated from LANDSAT data worth the effort?

Please feel free to add any items which will make the evaluation more meaningful. I am enclosing for your information a copy of the New Orleans District evaluation of a 1975 ERL product.

Sincerely,

RICHARD N. FOREMAN
CPT, CE
R&D Coordinator

1 Incl
As stated

CF:

USA Eng Div, S. Atlantic
(SADEN-FG) wo Incl
ETL-PRO wo Incl

APPENDIX D

Demonstration Cost

DEMONSTRATION COST

The $56,532 total cost for the demonstration includes costs for the Corps of Engineers (Wilmington and Jacksonville Districts and ETL), ERL Civil Service personnel and ERL in-house contractor support. Each of these costs has been divided between the two study areas as shown:

	OCE	ERL Civil Service	ERL Contractor	Total
Wilmington	$8,597	$6,150	$25,322	$40.069
Jacksonville	$2,969	$6,150	$ 7,344	$16,463
				$56,532

The OCE cost includes coordination and training expenses for District and ETL personnel, as well as the costs for field work and evaluation.

The ERL Civil Service cost is for ERL personnel involved in planning and coordinating the demonstration and working with Corps personnel to produce the classifications.

The ERL Contractor cost is $32,666 for support provided by ERL's in-house contractor. 1,219 man-hours of direct labor were charged to this phase of the demonstration by the contractor.

Personnel at ERL estimate that the unsupervised Program SEARCH (Jacksonville) requires 29% of the man-hour effort of the supervised (Wilmington) method of classification. Dividing the support contractor cost on that basis, Jacksonville cost $7,344 and Wilmington cost $25,322. Although based on direct labor man-hours, the cost includes ERL's maintenance and operating (functional support) overhead charges. ERL, as a research and "technology transfer" organization, has an overhead structure which is probably more expensive than that of a typical production organization. (Inclosure) For the demonstration, the functional support charge added $1.42 to every $1.00 spent for direct support contractor labor.

INCLOSURE

APPENDIX D

NASA/ERL OVERHEAD

Information for this Inclosure
was provided by NASA/ERL.

The 1219 man-hours of Direct Support effort for the demonstration were for Data Processing and some Data Preparation (mainly photo lab support of preparing the classification products). Data Acquisition work was done by Jacksonville and Wilmington District personnel.

Functional Support is computed and charged monthly. The charge is based on ERL's actual expenses for the month and is prorated among ERL's customers based on the Direct Support man-hours charged to each. The demonstration was charged an average of 1.33 Functional Support hours for each Direct Support man-hour. $11.84 per hour is a typical Functional Support rate for the period of the demonstration.

1219 hours at \$26.80 = \$32,666.

Direct Support

Composite Labor rate		7.25
+ Contractor o/h	(36%)	9.86
+ G&A	(7%)	10.55
+ Fee	(5%)	11.08

Burdened rate = 11.08/hr

Direct Support cost = 11.08 x 1219 = \$13,507.

Functional Support (Overhead) - 1618 hours

Composite Labor rate		7.75*
+ Contractor o/h	(36%)	10.54
+ G&A	(7%)	11.28
+ Fee	(5%)	11.84

Burdened rate = 11.84/hr

Functional support cost = 11.84 x 1618 = \$19,159.

Overhead Rates

$\frac{19159}{13507}$ = 1.42; 142% cost overhead

$\frac{1618}{1219}$ = 1.33; 133% hourly overhead

* Higher than direct support rate because of higher levels of expertise required in development work.

Description of Support:

Direct Support

- o Data Preparation (ground field work, photo interpreting, report organization and printing, charts and mosaics preparation, photo lab printing).

- o Data Acquisition (field work, lab analysis, research vehicle operation for data collection purposes).

- o Data Processing (Interaction with computer through display devices for processing of raw data, not including computer maintenance and operation).

Functional Support

1- Computer operation

2- Computer maintenance

3- Telephones, vehicles, property maintenance, relocation activities, etc.

4- Program and technique development including application program software, systems software and systems hardware integration.

5- Research vehicle (boat, truck, aircraft) maintenance.

6- Wet lab, soil lab, instrument calibration lab maintenance.

7- Modification of vehicles and instruments for technique development purposes.

8- Total support contract administration.

1, 2, 3, and a small portion of 8 are typical operational overhead activities; 4, 5, 6, 7, are associated with the development activities of ERL. 1, 2, 3 and a small portion of 8 represent less than 1/3 of the total overhead cost.

APPENDIX E

Production Cost

for

LANDSAT Techniques

Production Cost

The $56,532 cost of the demonstration should not be considered typical for generating land cover information from LANDSAT data. Some discussion of average production costs is probably in order. The best units in which to describe production costs are dollars per LANDSAT scene. Most civil works projects involve areas of less than a full LANDSAT scene and, with the exceptions of ground truth and training site selection effort, the costs for processing LANDSAT data increase slowly for up to a full scene.

Unfortunately, there is no typical LANDSAT scene or civil works project. The difficulty (and cost) of processing LANDSAT data depends on the desired detail of information about the project area, they physical characteristics of the project area, and the resources available to process the LANDSAT data. Costs will vary quite widely as any of these factors change. In developing a "normal production cost," two approaches were used. Neither approach fully accommodates the range of factors which affect the production costs.

One approach was to develop the annual cost to maintain a dedicated processing system and then assume that it is used to process a given number of scenes each year. An average cost per scene figured from that data should include some variations between individual projects and LANDSAT scenes. This method gave a range of costs from $9,000 to $13,000 to process a LANDSAT scene using the supervised method. The range of figures includes consideration of the amount of computer support already available and assumes utilization of the system for from twenty to fifty scenes each year. This approach is further described at Inclosure 1.

The second approach involved cost data from other projects which used LANDSAT data. Information was obtained for three such projects: an EPA study of vegetation in the Florida coastal zone, a State of Georgia program to provide environmental data to a number of users, and a proposed contract in support of land cover mapping in the Dan River Basin of Virginia and North Carolina. Comparisons among the cost data were again complicated by variations in size and complexity of the areas and in the scope and purpose of the studies which used the LANDSAT data. There was also difficulty in identifying all of the significant cost elements and ensuring that they were considered in a uniform manner. A range of costs from $8,927 to $23,800 per LANDSAT scene was developed. A further description of this approach is at Inclosure 2.

INCLOSURE 1 TO

APPENDIX E

Cost for Dedicated System

DEDICATED SYSTEM

The cost to process LANDSAT data on a dedicated in-house system was assembled from several sources. It is made up of separate cost elements, which are added in order to arrive at a total cost. The total cost is figured in dollars per LANDSAT scene.

Hardware:

The hardware cost element is based on configuration 2 of a low cost data analysis system designed by NASA (Ref. E-1-1). The cost is figured two ways: acquisition of a complete new processing system, and augmentation of an existing computer facility with hardware needed to process LANDSAT data. An eight year hardware life cycle is assumed.

	New System	Existing System
Computer	$135,000	-----------
Printer/Plotter	20,000	-----------
Image Display System	33,000	$33,000
tape punch	2,800	2,800
Total	$190,800	$35,800
8 yr. life cycle	$ 23,850/yr	$ 4, 475/yr*

* Does not include share of existing equipment to be replaced within eight years.

Staff:

The staffing requirement to operate a data processing system is based on the recommendations of NASA ERL in its documentation of the South Louisiana Environmental Information System. (Ref. E-1-2) It is assumed that a complete staff would be needed -- either to operate a new system or because the staff at an existing facility would not be able to absorb the added workload of processing LANDSAT data.

Staff	GS-Grade	Salary (Oct '77)
1 computer operator	6	$ 12,000
1 maintenance engineer	11	20,000*
1 output operator	4	10,000
1 systems programmer	11	20,000
4 ea. data processing personnel	4	@10,000
Total Salary Cost		$102,000/yr

* A savings of up to $20,000 might be realized if the maintenance capability is contracted.

A one-time training expense of $20,000 for the staff is necessary.

Overhead:

The costs to house and operate the data processing system cannot be estimated. They depend greatly on the location of the system and on whether it is part of or collocated with an existing computer facility.

Facility:

The cost to maintain and operate a facility for processing LANDSAT data is the sum of the Hardware, Staff, and Overhead costs.

	New System	Existing System
Hardware	$ 23,850/yr	$ 4,475/yr
Staff	102,000/yr	102,000/yr
Overhead	-----------	-----------
Total	$125,850/yr	$106,475/yr

NASA ERL estimates that the data processing system should be able to produce land cover classification data for a maximum of 50 LANDSAT scenes each year. A minimum number of 20 scenes per year should allow for inexperience of processing personnel and complex study areas or projects. The Facility cost per LANDSAT scene would thus be:

	New System	Existing System
20 scenes/yr	$6,293	$5,324
50 scenes/yr	$2,517	$2,130

Materials, Expenses:

Computer analysis is not the only cost of producing land cover classifications from LANDSAT data. Other costs include the acquisition of LANDSAT computer-compatible tapes and the performance of field work in the study area. The field work would include ground truth effort prior to the classification and verification effort afterward. Maps and aerial photographs are generally required in support of the field work. This cost will vary greatly, as there is no "typical" project or study area, but a good description of these expenses for one project is given in the cost analysis report for the Florida Coastal Zone Remote Sensing Demonstration Project. (Ref. E-1-3) The cost for LANDSAT tapes, aerial photography, and ground truth and verification effort for that project was $6,750/scene. In a production program the organization requesting the analysis should probably be expected to fund this cost.

Total Cost:

The total cost for processing LANDSAT data on a dedicated system will be the sum of the Facility and the Materials, Expense costs. The Facility cost can be simplified into a Best Case (50 scenes per year on an existing system) and Worst Case (20 scenes per year on a new system) consideration.

	Best Case	Worst Case
Facility	$2,130/scene	$ 6,293/scene
Materials, Expenses	6,750/scene	6,750/scene
Total Cost	$8,880/scene	$13,043/scene

References

E-1-1. Whitley, Sidney L.: Low-Cost Data Analysis Systems for Processing Multispectral Scanner Data. NASA TR R-467, October 1976

E-1-2. Anon.: South Louisiana Environmental Information System - Interim Report. ERL and NSTL Report No. 152, November 1975

E-1-3. Anon.: Cost Analysis Report for the EPA/NASA Florida Coastal Zone Remote Sensing Demonstration Project. (See also: Appendix F)

INCLOSURE 2 TO

APPENDIX E

Cost for Other Projects

COST FOR OTHER PROJECTS

Cost data for three projects was used to provide a comparison to the costs of the demonstration (Appendix D) and of a dedicated processing capability (Appendix E, Inclosure 1). This data should not be converted to an average cost per project because the projects are in different areas and for different purposes. The projects are:

a. EPA/NASA Florida Coastal Zone Remote Sensing Demonstration Project (Ref. E-2-1)

b. Georgia Natural Resources Information System (Ref. E-2-2)

c. Dan River Basin (Ref E-2-3)

Table F-1 shows the three projects with their costs expressed as cost elements. The separate cost elements were used in order to ensure that similar expenses were considered for all three projects.

TABLE F-1

PROJECT COSTS

	Planning	Ground Truth	Processing: Labor	Processing: Materials	Processing: Total	Verification	Total	Remarks
EPA	2113	4569	3000	375	3375	1460	11,517	Probably does not include overhead for labor costs.
Georgia	----	4569	----	200	2898	1460	8,927	EPA costs used for ground truth, verification.
Dan River	4200 1800	4800	----	---	9900	3100	23,800	Budgetary estimate

References

E-2-1. Anon.: Cost Analysis Report for the EPA/NASA Florida Coastal Zone Remote Sensing Demonstration Project. (Attached)

E-2-2. Zimmer, R. P., et al: Cost Benefit Analysis of the Transfer of NASA Remote Sensing Technology to the State of Georgia. Engineering Experiment Station, Georgia Institute of Technology, November 1977. Prepared for NASA Earth Resources Laboratory Contract NAS9-15283

E-2-3. Anon.: Cost Estimates for Land Cover Mapping of the Dan River Basin. (Attached)

COST ANALYSIS REPORT
FOR THE
EPA/NASA FLORIDA COASTAL ZONE
REMOTE SENSING DEMONSTRATION PROJECT

Ref. E-2-1

INTRODUCTION

Background

The NASA Earth Resources Laboratory has developed a remote-sensing technique for vegetation classification of the Louisiana and Mississippi coastal areas by using LANDSAT and aircraft data. To determine whether this same technique could be used in Florida, a cooperative project was set up between the NASA Earth Resources Laboratory, EPA/Region IV (Surveillance and Analysis Division) and EPA/Las Vegas (Environmental Monitoring and Support Laboratory).

Goals of the project were to develop the remote sensing application and to evaluate it as a tool to inventory vegetation communities and land use, monitor wetlands for stress and define wetland boundaries in the Florida coastal zone study area. Also, in a broader sense, the project was designed to demonstrate remote sensing applications EPA is addressing in various coastal and wetland zones.

Purpose

The purpose of this document is to present cost data for the remote sensing study of vegetation in the Florida study area so that a comparison can be made to costs of similar data acquired by conventional methods. EPA's Surveillance and Analysis Division will conduct a study of costs of these conventional methods.

Scope

The data presented in the following pages reflect costs for acquisition, processing, and analysis of airborne and satellite-borne (LANDSAT) data and for the preparation of these data for technical reporting and presentation. This cost analysis was developed for the classification of approximately 10,000 scan lines of aircraft data over approximately 150 square miles and two computer compatible tapes of LANDSAT data covering about 1500 sq.mi.(Land). The results do not imply a cost figure per scan line or per tape. The classification of additional airborne or LANDSAT data would not increase costs proportionately since many of the items, once accounted, would not be repeated in the classification of addditional data.

Approach

The costs presented herein were compiled after completion of processing and presentation of airborne data and processing of LANDSAT data. Costs for the remaining work to be done on preparation of LANDSAT data have been projected. Costs for materials, services, and travel and lodging expenses within the project area were verified by receipt or by catalog prices. Transportation expenses to and from the site are not included. Labor costs were retrieved from project records and support contractor job orders. Where possible, project costs have been separated into those associated with airborne data and those associated with LANDSAT data.

RESULTS AND DISCUSSION

Table I summarizes total costs for the Demonstration Project. Tables II through V detail itemized costs for project planning, data acquisition, data processing and preparation, and results verification, respectively.

Separation of some of the costs for LANDSAT and aircraft project planning, data acquisition, and processing and preparation was not done when costs were actually incurred. Separate planning meetings were not convened, for instance, for LANDSAT and aircraft data processing. In view of this, separation of many of these costs have been estimated and noted in Tables II through V. Details delineated in Tables II through V allow estimates of total costs of a project such as this using data collected solely by either aircraft or satellite. Using the data in Tables II through V, Table VI presents a comparison of estimated costs of this project had only aircraft or satellite data been used.

TABLE I

PROJECT COST

EPA/NASA FLORIDA COASTAL ZONE
REMOTE SENSING DEMONSTRATION PROJECT

Project Planning and Preparation----------	4,125
Data Acquisition--------------------------	9,483
Data Processing---------------------------	7,850
Verification of Results-------------------	1,460
TOTAL PROJECT COST--------------	$22,918

TABLE II

ITEMIZED COST - PROJECT PLANNING AND PREPARATION

	Actual LANDSAT & Aircraft Project	Projected LANDSAT Project Only	Projected Aircraft Project Only
Planning, Supervision and Coordination			
NASA Civil Service - 80 manhours @ $10.00/manhour	$800.	$500.	$300.
Support Contractor 40 manhours @ $10.00/manhour	400.	250.	150.
EPA - 40 manhours @ $10.00/manhour	400.	300.	100.
Mission Preparation			
Labor (ERL Support Contractor)			
Photomosaic preparation - 50 man-hours @ $10.00/manhour	500.	0[a]	0[a]
Selection of training samples - 49 manhours @ $10.00/manhour	490.	475.	157.
Mission package preparation - 20 manhours @ $10.00/manhour	200.	80.	200.
Literature Search - 80 manhours @ $10.00/manhour	800.	0[b]	0[b]
Materials			
Reference Book (Univ. of Miami)	24.	0[b]	0[b]
Color IR Prints (Mark Hurd Corp.)	500.	500.	500.
Black & White Prints (USPI)	3.	0	3.
Maps & Graphic supplies (Support Contractor Stock)	8.	8.	8.
TOTAL COST OF PROJECT PLANNING & PREPARATION	$4,125.	$2,113.	$1,418.

NOTES:

a. Photomosaic not considered necessary for general/production (Non R&D) Remote Sensing Exercises.

b. Not considered necessary when field personnel are thoroughly familiar with test site.

TABLE III
ITEMIZED COST - DATA ACQUISITION

	Actual LANDSAT & Aircraft Project	Projected LANDSAT Project Only	Projected Aircraft Project Only
Satellite Data			
LANDSAT Tape	$200.	$200.	0
Aircraft Data Collection			
Magnetic Tape for RS-18 MSS	260.	0	260.
Aircraft fuel and oil	383.	0	383.
9" color infrared film	261.	0	261.
Support Contractor			
Salaries - 243 manhours @ $10.00/ manhour	2,430.	0	2,430.
Expenses (food, lodging, trans- portation)	1,216	0	1,216.
Ground Truth Data Collection			
Support Contractor			
Salaries - 40 manhours @ $10.00/ manhour	400.	388.	128.
Expenses (food, lodging, trans.)	184.	178.	59.
NASA Civil Service			
Salaries - 40 manhours @ $10.00/ manhour	400.	388.	128.
Expenses (food, lodging, trans.)	184.	178.	59.
EPA			
Salaries - 80 manhours @ $10.00/ manhour	800.	776.	256.
Expenses (food, lodging, trans).	368.	356.	118.
Materials and Services			
Helicopter Rental			
Support Contractor	493.	478.	158.
EPA	884.	857.	283.

TABLE III

(Continued)

	Actual LANDSAT & Aircraft Project	Projected LANDSAT Project Only	Projected Aircraft Project Only
Ground Truth Data Preparation and Cataloguing Preparation of Herbarium samples and integration of data cards and ground truth forms into file system. 100 manhours @$10.00/ manhour.	1,000.	970.	320.
TOTAL DATA ACQUISITION COST	$9,483.	$4,788.	$6,065.

TABLE IV

ITEMIZED COSTS - DATA PROCESSING AND PREPARATION

	Actual LANDSAT & Aircraft Project	Projected LANDSAT Project Only	Projected Aircraft Project Only
LANDSAT Data Processing			
Computer Classification of data			
NASA Civil Service - 80 manhours A $10.00/manhour	$800.	$800.	0
Support Contractor - 200 manhours @ $10.00/manhour	2,000.	2,000.	0
Product Preparation			
Photographic Laboratory	175.	175.	0
Graphics support - 20 man-hours @ $10.00 manhour	200.	200.	0
Aircraft Data Processing			
Computer Classification of Data			
NASA Civil Service - 80 man-hours @ $10.00/manhour	800.	0	800.
Support Contractor - 350 man-hours @ $10.00/manhour	3.500.	0	3.500.
Product Preparation			
Photographic Laboratory	175.	0	175.
Graphics support - 20 man-hours @ 10.00/manhour	200.	0	200.
TOTAL COST OF DATA PROCESSING	$7,850.	$3,175.	$4,675.

TABLE V

ITEMIZED COSTS - VERIFICATION OF RESULTS (ACCURACY CHECK)[a]

Site Visitation by EPA (Projection)	
Salaries - 48 manhours @ $10.00/manhour	$ 480.
Expenses (food, lodging, transportation)	300.
Helicopter Rental	680.
TOTAL COST OF VERIFICATION	$1,460.

NOTES:

a. This effort is not considered necessary if the accuracy for the technique has been previously estab lished by the user to his satisfaction.

TABLE VI

COMPARISON OF ESTIMATED COSTS FOR THE FLORIDA COASTAL ZONE REMOTE SENSING DEMONSTRATION PROJECT USING ONLY LANDSAT OR AIRCRAFT DATA[a]

ITEM	LANDSAT COST ESTIMATE[d]	AIRCRAFT COST ESTIMATE[e]
Project Planning and Preparation	$ 2,313.	$ 1,618.
Data Acquisition	4,788.	6,065.
Data Processing & Preparation		
NASA Civil Service	800.	800.
Other support work[b]	2,375.	3,875.
SUBTOTAL	$10,276.	$12,358.
Accuracy Verification[c]	(1,460.)	(1,460.)
TOTAL	($11,736.)	($13,818.)

NOTES:

a. Estimated costs based on defined project test area size. The classification of additional airborne or LANDSAT data would not increase costs proportionately since many items, once accounted for, would not be repeated for additional data.

b. Data processing and preparation Item is similar in content to the service obtainable from private industry.

c. This effort is not considered necessary if the accuracy for the remote sensing technique has been previously established by the user to his satisfaction.

d. Estimate based on a land area size of approximately 1500 square miles.

e. Estimate based on a land area size of approximately 150 square miles.

COST ESTIMATES FOR LAND COVER MAPPING OF THE DAN RIVER BASIN

A.	**Preliminary**	
	1. Education	$ 1,700.00
	2. Coordination with Contractor	1,200.00
	3. Travel (air fare, rental car)	1,000.00
	4. Per Diem	300.00
		$ 4,200.00
B.	**Ground Truthing**	
	1. Field time	$ 3,700.00
	2. Per Diem	1,100.00
		$ 4,800.00
C.	**Bendix Contract**	
	1. Color-coded map (1:100,000 scale) merged, mosaic, mounted and annotated and report	$ 7,900.00
	2. Land cover tapes-corrected and transcribed to UTM projection (50 meter on a side cell size) $.50/square mile	2,000.00
		$ 9,900.00
D.	**Verification**	
	1. Field time	$ 2,400.00
	2. Per Diem	700.00
		$ 3,100.00
E.	**Base Map and Miscellaneous**	$ 1,800.00
	TOTAL COST	$23,800.00