DEVELOPMENT AND APPLICATION OF OPERATIONAL TECHNIQUES FOR THE INVENTORY AND MONITORING OF RESOURCES AND USES FOR THE TEXAS COASTAL ZONE

Peggy Harwood
Patricia Malin
The General Land Office
1700 North Congress
Austin, Texas 78701

Robert Finley
Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas 78712

Samuel McCulloch
David Murphy
Bill Hupp
Texas Natural Resources Information Systems
Austin, Texas 78701

John A. Schell
Remote Sensing Center
Texas A&M University
College Station, Texas 77840

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16. Abstract

Four Landsat scenes were analysed for the Harbor Island Area Test Site to produce land cover and land use maps using both image interpretation and computer-assisted techniques. When evaluated against aerial photography, the mean "accuracy" for three scenes was 84% for the image interpretation product, and 62% for the computer-assisted classification maps. Analysis of the fourth scene was not completed using the image interpretation technique, because of a poor quality, false color composite, but was available from the computer technique. Preliminary results indicate that these Landsat products can be applied to a variety of planning and management activities in the Texas Coastal Zone. For example, computer-derived land/water maps can be used with tide gage data to extend shoreline boundaries, dependent on a known water level, away from surveyed areas for management purposes. Also, Landsat images can be used to monitor existing spoil areas and to evaluate proposed sites for the deposition of dredged materials along navigation channels.

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
1.1	Scope and Purpose of Report	1
1.2	Summary of Work Performed	1
2.0	PROBLEMS	2
2.1	Problems Associated with a Poor Quality False-Color Composite	2
3.0	ACCOMPLISHMENTS	4
3.1	Data Acquisition	4
3.2	Examination of Test Site 4 (Harbor Island Area)	4
3.2.1	Description of Site 4	4
3.2.1.1	Landsat Data for Test Site 4	6
3.2.2	Image Interpretation Analysis of Site 4	8
3.2.2.1	Change Detection Based on Reflectance Differences	15
3.2.2.2	Dredge Spoil Detection	16
3.2.3	Computer-Assisted Classification of Site 4	17
3.2.3.1	Classification Scheme for Computer-Assisted Analysis	17
3.2.3.2	Correlation Procedures	22
3.2.3.3	Progress in Computer-Assisted Analysis	22
3.2.4	Evaluation of Classification Accuracy	25
3.2.4.1	Accuracy of Image Interpretation Products	25
3.2.4.2	Accuracy of Computer Classification	29
3.2.5	Application of Landsat Products to Management Activities	34

Page

3.2.5.1 Objectives for the Site 4 Test 34

3.2.5.2 Information from Landsat Products 37

3.2.5.3 Summary of Findings 43

3.2.6 Progress of Cost-Savings Evaluation 44

3.2.6.1 Major Objectives and Limitations of the Study 49

3.2.6.2 Preliminary Accomplishments 52

3.3 Special Image Interpretation Studies 54

3.3.1 Tidal Inundation Study 54

3.3.2 A Landsat Study of Turbidity and Circulation Off Aransas Pass, Texas 56

3.4 Changes in the Computer-Assisted Classification Program 59

3.4.1 Required Improvements in Analysis Procedures and Programs 66

3.5 Program for the Next Reporting Interval 68

4.0 SIGNIFICANT RESULTS 73

5.0 PUBLICATIONS 73

6.0 RECOMMENDATIONS 74

7.0 FUNDS EXPENDED 74

8.0 DATA USE AS OF FEBRUARY 28, 1977 75

9.0 AIRCRAFT DATA 76

REFERENCES

APPENDICES

A Landsat Coverage of the Test Sites 2, 3, 4, 5 for Landsat Investigation #23790

B Work Accomplished to Date in the Production of Computer-Generated Maps for each Scene

C Landsat Mr-Clean

D Landsat Detect

LIST OF ILLUSTRATIONS

Figure		Page
1.	Geographic Features in Test Site 4, the Harbor Island Area.	5
2.	Line Boundary of Test Site 4, 25 February 1975 (Scene 2034-16202).	10
3.	Line Boundary Map of Test Site 4, 2 February 1976 (Scene 2376-16172).	12
4.	Comprehensive Summary of all Spoil Dispositied along the Corpus Christi and Aransas Channels between 21 Jan. 1973-2 Feb. 1976.	18
5.	Chronological Distribution of Spoil Dispositied along the Corpus Christi and Aransas Channels.	18
6.	Stepwise Hierarchical Tree Derived from HGROUP.	23
7.	Plot of Spectral Means Derived from ISOCLS Results.	24
8.	Summary of Interpretation Accuracy for all Categories in the Harbor Island Area Test Site.	30
9.	Location of areas within Harbor Island Area Test Site for comparing Classification Results of Landsat Scenes.	36
10.	Portion of Test Site as depicted on the Detection and Mapping (DAM) Display (National Aeronautical and Space Administration 1976) with an Overlay showing the Numbered State-owned Land Tracts and USGS Topographic Information.	38
11.	Map showing Change in Area of Emergent Marsh, Tidal Flat and Beach at Pass Cavallo due to Wind-tide of 25 February 1975.	55
12.	Time-history of Wind Data at Victoria, Texas.	58
13a.	Classification Display before using Mr-Clean.	60
13b.	Classification Display after processing with Mr.-Clean.	61
14a.	Part of Site 4 near Port Ingleside on the Corpus Christi Ship Channel on 25 February 1975 (Scene 2034-16202).	63
14b.	Same Area as Figure 14a, but 6 Months later on 10 July 1976 (Scene 3, 5082-16080).	64
14c.	Change Detection Comparing Scene 1 to Scene 3.	65

LIST OF TABLES

Table		Page
1.	Landsat Data for Harbor Island Test Site.	7
2.	Landsat Images used in Dredge Spoil Study.	7
3.	Land Cover and Land Use Classification for use with Unenhanced Landsat Data in the Texas Coastal Zone.	13
4.	Land Cover and Land Use Classification for use with Landsat Computer Compatible Tapes.	20
5.	LARSYS/ISOCLS Parameters.	25
6.	Steps in Computer-Assisted Analysis of Landsat Data	26
7.	Accuracy Analysis of Landsat Image Interpretation Map Products, Harbor Island Test Site.	28
8.	Matrix showing Distribution of Computer Classification relative to Image Interpretation of Landsat Data.	31
9.	Accuracy Analysis of Landsat Computer-Generated Map Products, Harbor Island Test Site.	33
10.	Examples of Management Activities and Issues in the Harbor Island Area occuring between 1973 and 1976.	35
11.	Information for Computing Costs of ADP Interpretation and Image Interpretation.	48
12.	Survey Questionnaire on Costs of the Environmental-Geology Map.	50
13.	Tables for Image Interpretation Map Product.	53

1.0 INTRODUCTION

1.1 Scope and Purpose of Report

This progress report covers activities during three quarters, June 1976 through February 1977, for LANDSAT Investigation #23790 This investigation was funded for 19 months to develop techniques in Texas state agencies for using Landsat data to inventory and monitor coastal resources and uses. The General Land Office (GLO) is the Texas agency coordinating this investigation. Other participating agencies are the Bureau of Economic Geology (BEG), Texas Natural Resources Information System (TNRIS), and Texas Parks and Wildlife Department (TPWD).

1.2 Summary of Work Performed

During this reporting period, most activities focused on completing the "test" of using image interpretation and computer-assisted techniques to address General Land Office coastal management concerns. Specific accomplishments included:

1) detailed analysis and accuracy evaluation of 4 Landsat scenes of the Harbor Island Area Test Site on the Central Texas coast,

2) collection of data for the cost-savings analysis,

3) application of Landsat-derived map products to typical coastal management concerns in the Harbor Island Area, and

4) special image interpretation studies, not a part of the Harbor Island Area Test.

2.0 PROBLEMS

Several unexpected delays have been experienced during the past 6-8 months that resulted in a request for a no-cost extension for 5 months beyond the original contract period ending on March 25, 1977. Extension of the contract through August 1977 was granted to provide ample time to complete all documentation and reporting on this investigation.

Delays occurred during the summer and fall in part because of the user workload imposed on the Texas Water Development Board's computer system, which is shared with the Texas Natural Resources Information System and other state agencies. A larger computer system has subsequently been installed, eliminating such delays. However, analysis runs for Site 4 were not completed until January, which in turn delayed our completion of the evaluation of the products and the cost study.

Drafts for sections of the final report have been completed concerning the image interpretation results and the cost study. Documentation on the evaluation of product utility and "accuracy", and on the computer-related work is also nearly complete. The draft final report will be completed by early June, allowing 3 months for review and final printing.

2.1 Problems Associated with a Poor Quality False-Color Composite

To complete the study of the Harbor Island Test Site, a winter scene was sought to compare with the February 1975 and February 1976 scenes. Due to cloud cover constraints and the requirement that satisfactory digital data also be available, the Landsat-1 imagery of 16 December 1972 (scene 1146-16320) was selected. Special processing was needed, however, to produce the false-color composite transparency, due to poor data in Band 7. Band 6 was therefore subsituted for the 0.8 - 1.1 um data.

The false-color composite image received from the EROS Data Center was not satisfactory for mapping via the image interpretation procedure. A problem in registration during exposure of the three dye layers of the film resulted in a "double image" on the transparency in colors of blue and red. The misregistration was serious enough to obscure the boundaries of most units and to cause obviously false information to be created. An example of the latter is the occurrence of an infrared response typical of vegetation within the tidal inlet waters of Aransas Pass.

Mapping of Test Site 4 was attempted using the black-and-white single band images, primarily Bands 5 and 6. A line boundary map was produced over the entire test site and the seaward half was classified as to land cover and land use. Results were poor compared to map results previously obtained using a good quality false-color composite, supplemented by single-band images where needed. Classification of vegetated areas was difficult, less confidence was placed in the boundaries drawn, and the classified areas were highly generalized. From this experience it may be concluded that a high-quality false-color composite image is critical to the optical image interpretation process.

3.0 ACCOMPLISHMENTS

3.1 Data Acquisition

The current status of Landsat data acquisition to support this investigation is reflected in Appendix A. There were no CCT's ordered during this reporting period. A majority of the image products ordered were related to a special feasibility study being conducted by the Bureau of Economic Geology on circulation in the bays of Test Site 4 and turbidity plumes in the nearshore Gulf of Mexico. The scenes ordered specifically for this study are noted in Appendix A. One order, for a color composite transparency of Landsat scene 1146-16320, was delayed due to the poor quality of the Band 7 image (apparently from scale/geometric distortions) which caused difficulties at the EROS Data Center in registering Bands 4, 5, and 7. An effort was made to obtain a better quality color composite by ordering one made from Bands 4, 5, and 6. However, the overall quality rating of the composite was still low, as noted in section 2.0.

3.2 Examination of Test Site 4 (Harbor Island Area)

3.2.1 Description of Site 4

Large areas of Site 4 (fig. 1) are covered by shallow water less than 3-4 feet deep, in which grows dense submergent vegetation or seagrasses. While Redfish Bay, between Harbor Island and the mainland, probably represents the largest area of seagrasses, other areas are also found within Harbor Island and on the bay side

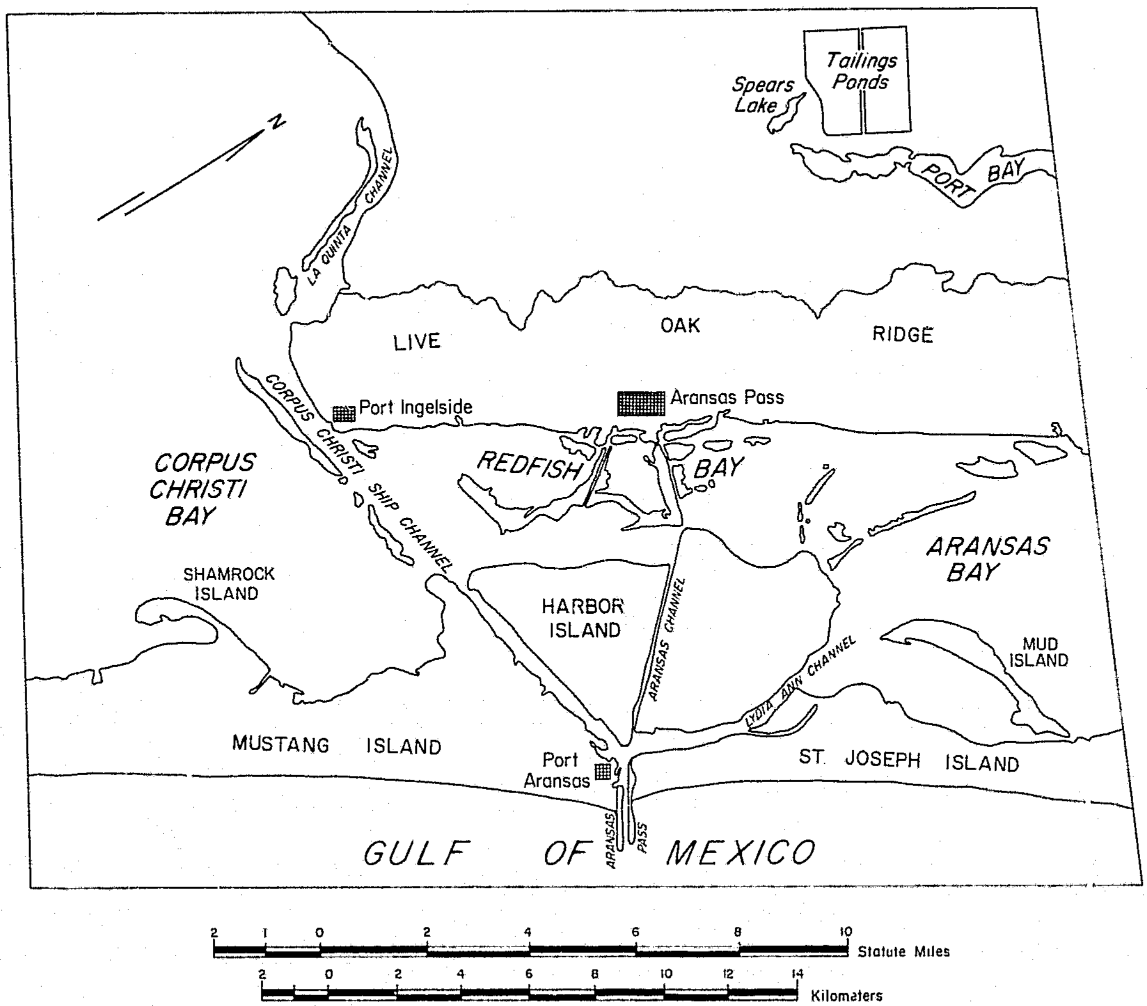


Figure 1. Geographic Features in Test Site 4, the Harbor Island Area.

of the coastal barrier islands. Extensive low marshes are found on Harbor Island which include Avicennia germinans (black mangrove), Spartina alterniflora (smooth cordgrass) and Batis maritima (maritime saltwort). S. alterniflora is also abundant throughout the area along the submergent to barely emergent margins of ponded water as well as in areas of generally bare substrate and scattered vegetation which would be termed tidal flats. Numerous dredged channels are utilized by commercial shipping accessing the Gulf of Mexico through Aransas Pass, hence the monitoring of dredge spoil is given more consideration here than in other test sites.

A number of urban and large industrial sites are found on the mainland portion of this test site. A live oak (Quercus virginiana) woodland is developed on the Pleistocene barrier-strandplain sands, while further inland, rangeland (brush and grass mixtures) is found on areas mapped as locally mud veneered sheet sands (Brown, et al., 1976). Interdistributary muds (Brown, et al., 1976) support a cropland area almost exclusively producing grain sorghum.

3.2.1.1 Landsat Data for Test Site 4

For the Harbor Island Area, four Landsat scenes were selected for analysis by both image interpretation and computer-assisted techniques (table 1). These images were cloud free over the test site. The image interpretation results for the 16 December 1972 scene, however, were not satisfactory because of a poor quality color composite (section 2.0). More winter scenes were selected because more winter scenes were available with low cloud cover and good quality. The summer scene was included to evaluate seasonal differ-

Table 1.

LANDSAT DATA FOR HARBOR ISLAND TEST SITE

Assigned Scene No.	Date	Scene ID	Quality
1	25 Feb. 1975	2034-16202	8888
2	2 Feb. 1976	2376-16172	not rated
3	10 July 1975	5082-16080	8888
4	16 Dec. 1972	1146-16320	8888

ences within the test site. In addition, Landsat imagery for ten dates between 21 January 1973 and 2 February 1976 (Bands 5 and 7 only) were used to study changes in the areal extent of barren spoil (table 2).

Table 2.

LANDSAT IMAGES USED IN DREDGE SPOIL STUDY

Date	Image I.D. No.	Band
21 Jan. 1973	1182-16315	5,7
14 June 1973	1326-16315	7
29 Mar. 1974	1614-16263	7
2 Aug. 1974	1740-16225	7
7 Sept. 1974	1776-16212	7
25 Feb. 1975	2034-16202	5,7
24 Mar. 1975	1974-16135	7
10 July 1975	5082-16080	5,7
17 Oct. 1975	2268-16184	7
2 Feb. 1976	2376-16172	5,7

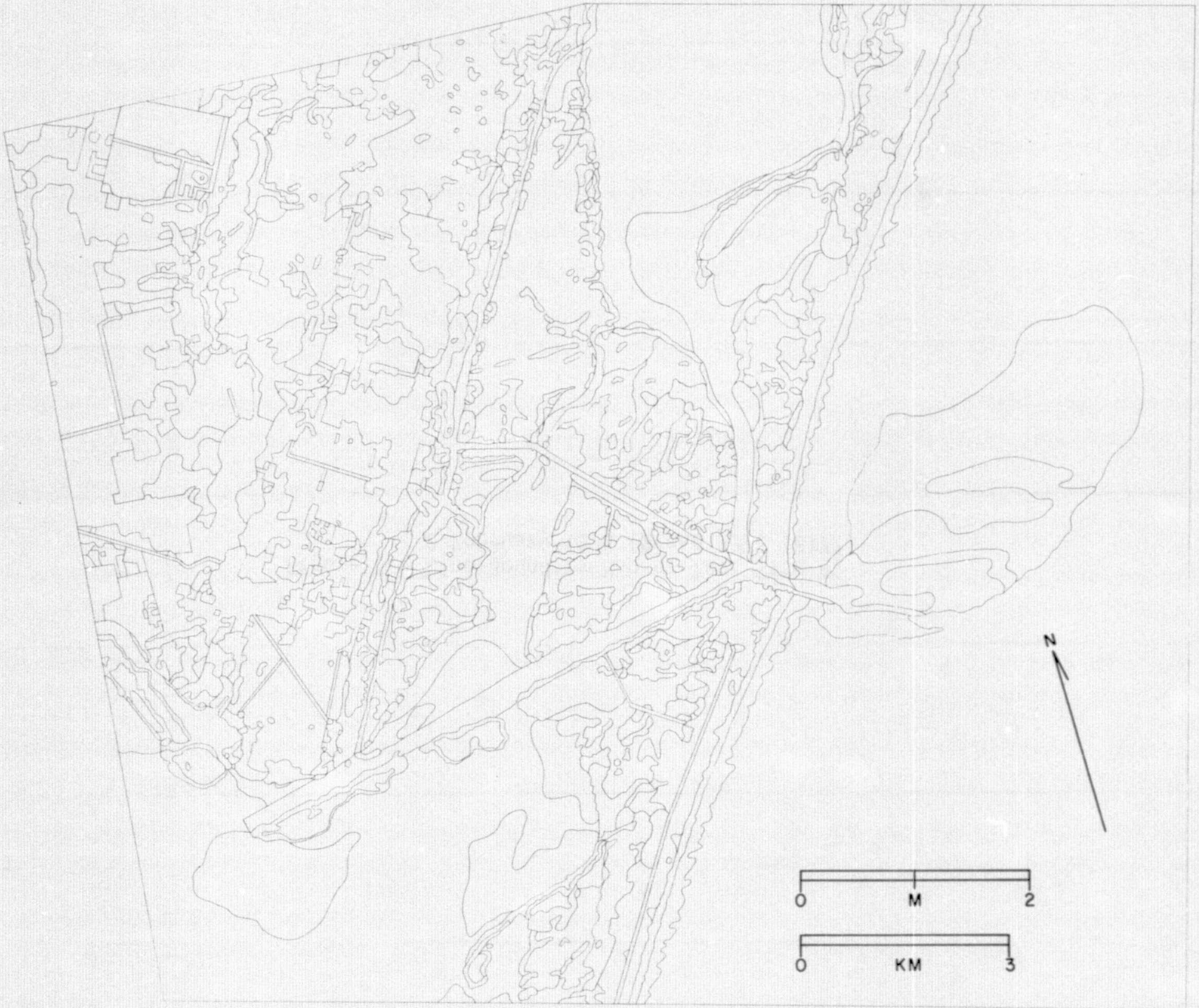
3.2.2 Image Interpretation Analysis of Site 4

Landsat scenes dating from 25 February 1975 (fig. 2), 2 February 1976 (fig. 3), and 10 July 1975 have been mapped and classified using the scheme in table 3.

Difficulty was encountered at times in placing the boundary between seagrass and algal flats, tidal flats, and low marsh as a result of the intermixing of these units in the natural environment. Many narrow strips of marsh were not detected, or were included in the tidal flat category, due to the dominant reflectance of the wet substrate or of ponded water. Bay-margin sand and shell berms, which should be classified as beaches, are difficult to distinguish from adjoining tidal flats and areas of shallow water because they are relatively narrow. Along the northeast margin of Redfish Bay the high-reflectance subaerial sand and shell accumulations are less than 80 m. wide in many areas. Their light blue color on the false color composite resembles that of the wide areas of tidal flat behind Mustang Island or on Harbor Island.

On the barrier islands the areas mapped as beach include sandflats with wind-shadow dunes, as well as washover channels, all of which have high reflectance and therefore indistinguishable mutual boundaries. Vegetated dunes behind the beach are not readily separated from the adjoining vegetated barrier flat but can be differentiated where they occur within or adjacent to the town of Port Aransas. Some small units of barren dunes have been mapped on Mustang Island where they occur as blowout complexes extending from the beach into the vegetated barrier flat.

Figure 2. Line Boundary of Test Site 4,
25 February 1975 (Scene 2034-16202)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KM
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Figure 3. Line Boundary Map of Test Site 4, 2 February 1976 (Scene 2376-16172)

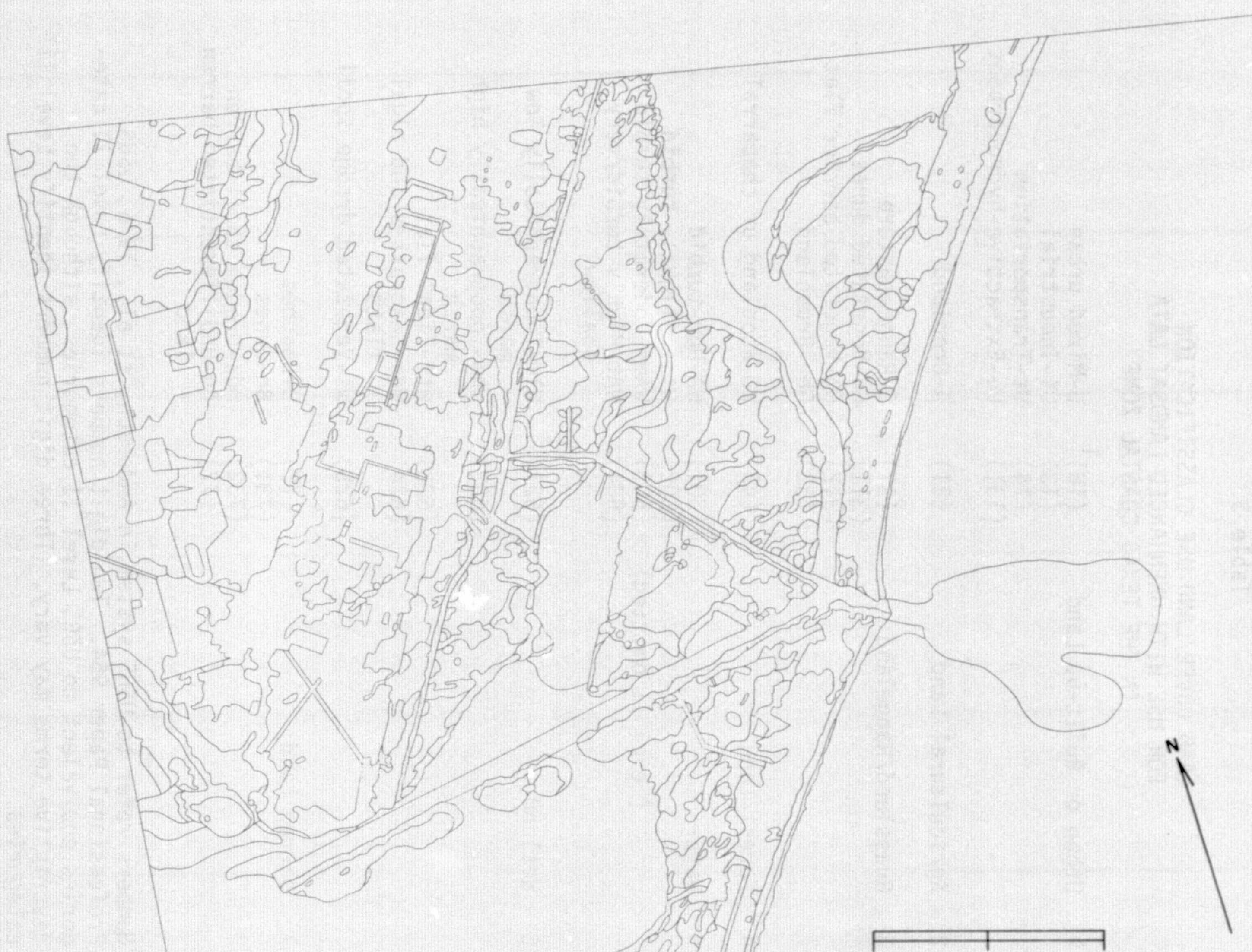
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Table 3.

LAND COVER/LAND USE CLASSIFICATION
FOR USE WITH UNENHANCED LANDSAT DATA
IN THE TEXAS COASTAL ZONE

1	Urban or Built-up Land	(16)[1]	U-Mixed urban
		(13)	Ui-Industrial
		(14)	Ut-Transportation
		(131)	Ue-Extractive-hydrocarbons
2	Agricultural Land	(21)	A-Cropland
3	Grassland/Rangeland	(31)	G-Range-pasture
		(311)	Gd-Vegetated dunes
		(312)	Gb-Vegetated barrier flat
		(32)	Gbr-Brushland
4	Forest Land	(43)	WO-Woodland or chaparral
5	Water	(501)	WA-Non-turbid
		(502)	WAst-Slightly turbid
	(Level II omitted)	(503)	WAmt-Moderately turbid
		(504)	WAt-Highly turbid/very shallow
6	Wetland	(621)	Wlm-Topographically low marsh
		(622)	Whm-Topographically high marsh
		(623)	Wtf-Tidal flat
		(624)	Wga-Seagrasses and algal flats
		(625)	Ws-Vegetated dredge spoil
7	Barren Land	(72)	B-Beaches
		(731)	Bd-Dunes
		(732)	Bds-Dredge spoil-barren
		(77)	Bu-Undifferentiated barren land

[1]Numbers refer to USGS system in Anderson, et al., 1976, USGS Professional Paper 964. Two digit numbers identify Level II categories equivalent to USGS Level II categories, although the descriptive terms may vary. Three digit numbers identify Level III categories.

The built-up area of Port Aransas is more difficult to recognize than the mainland urban areas of Aransas Pass and Ingleside. As in Site 5, where development on Padre Island was not discernable on the Landsat imagery, a characteristic urban signature is not developed unless the surrounding natural barrier island cover contrasts with some critical density of structures, roads and lawns. The setting of the mainland urban areas within a live oak woodland enhances their detectability since the imagery shows both a radiance contrast and a textural contrast between the adjacent areas.

The exact boundaries of each mainland urban area show some variation when maps produced from successive scenes are compared. These differences may be attributed to atmospheric and sun angle variations, differences in image processing, and differences in quality between images, as well as the interpreter's judgement in placing the unit boundary lines. Differences in the growth stage of vegetation (other than the live oak) also may be an important factor in delineating the urban areas, especially along margins where the density of development is low.

Landward of the live oak ridge is an area of mixed grass-and-brush rangeland. On the two winter scenes the entire area is mapped as grassland, while on the 10 July 1975 scene an area adjacent to Port Bay is considered brushland. This would be expected since the shrubs and scattered mesquite trees (<u>Prosopsis juliflora</u>) comprising the brushy vegetation are deciduous. The tonal and textural variation within the brushland unit is great, however, and field checking has shown both fairly open and dense brush growth to occur here.

Expected seasonal differences were also noted in the cropland areas on the northwest margin of the test site; grain sorghum was virtually the only crop observed to be growing during field studies. Winter scenes show barren fields consisting of a muddy substrate and defined by turnrows or other field boundaries. The false-color composite of the summer scene shows colors varying from bright red through pale red to bluish grays. Field checking in July 1976 indicated that sorghum fields were in various stages of development from just prior to full ripening through post-harvest stubble and plowed ground. In addition, grasses are allowed to invade some fields before harvest, which contributes more variation to the cropland signatures.

3.2.2.1 Change Detection Based on Reflectance Differences

A special study was made of reflectance changes between landsat images of Test Site 4, dating 21 January 1973, 25 February 1975, 10 July 1975 and 2 February 1976. The technique used was that of overlaying positive and negative film transparencies, enlarged to a scale of 1:125,000, as described in the December 1975 Quarterly Report (Jones et al., 1975b). The analysis was made at the Bureau of Economic Geology, and results indicate that temporal reflectance changes can be detected: 1) from areas cleared of native vegetation between image dates, 2) in agricultural areas due to the annual cycle of crop growth and 3) in drainage patterns across fields. The method was adequate for a qualitative overview of an area for general changes, but variations in fit between the uncontrolled enlarged images might be a problem in the investigation of specific sites, such as small units of cropland acreage.

Interpretations of Landsat radiance changes were confirmed by the NASA aerial photographs of about the same scale. The aerial photography clarified interpretation especially in those darker areas within croplands which did not follow field boundaries. These changes corresponded to subtle, natural drainage patterns.

Aerial photographs (NASA Mission 300) taken within a few days of the 25 February 1975 image were used as the control for interpreting change. The 1:120,000 scale photography was most useful for direct comparison with the Band 7 images because of the similarity with the enlarged 1:125,000 Landsat mapping scale. Because the vegetation conditions were the same when both the photography and the imagery were produced, the information provided by the color infrared photographs served as a means of checking the accuracy of interpretations of the transparency.

3.2.2.2 Dredge Spoil Detection

Another special study was made, of the changes in the areal extent of barren spoil using Landsat imagery for ten dates (table 2) during the period 21 January 1973 to 2 February 1976. Spoil islands along LaQuinta Channel and Corpus Christi Channel in Corpus Christi Bay and spoil in the East Flats area of Mustang Island were included. Band 5 images were used to locate spoil deposited on areas already subaerially exposed, while Band 7 data were used to delineate spoil dumped into water bodies to reate spoil islands. The high-contrast Band 7 images did not provide enough detail for the subaerial sites, hence the use of the

Band 5 images, supplemented by use of the false-color composite image when available.

Figure 4 provides a comprehensive summary of all spoil added in the study areas of Site 4 between 21 January 1973 and 2 February 1976 as detected on Landsat imagery. Most of the spoil was added to the channel-margin spoil islands and the East Flats area between 14 June 1973 and 29 March 1974, and between 7 September 1974 and 17 October 1975 (fig. 5). A large amount of spoil was also deposited on Harbor Island and Mustang Island between 14 June 1973 and 29 March 1974, and is evident on the Band 7 image from the latter date. No change in areal extent of certain barren spoil areas was evident on Band 5 data for Harbor and Mustang Islands between 21 January 1973 and 2 February 1976 (fig. 5). These results indicate that image interpretation of Landsat transparencies can be used to monitor dredge spoil placement, a capability which is enhanced by the high reflectance of the spoil material.

3.2.3 <u>Computer-Assisted Classification of Site 4</u>

3.2.3.1 <u>Classification Scheme for Computer-Assisted Analysis</u>

In the analysis of computer-generated maps covering Test Sites 2, 3, and 5, the resulting classes of land use and land cover were compared only in a general way to the classification scheme developed for Image Interpretation of the Landsat data (Harwood, et al., 1976, Table 1, p. 13). Initially, a relationship between the spectral classes and the classification scheme was established by visual correlation of the computer-generated maps with aerial

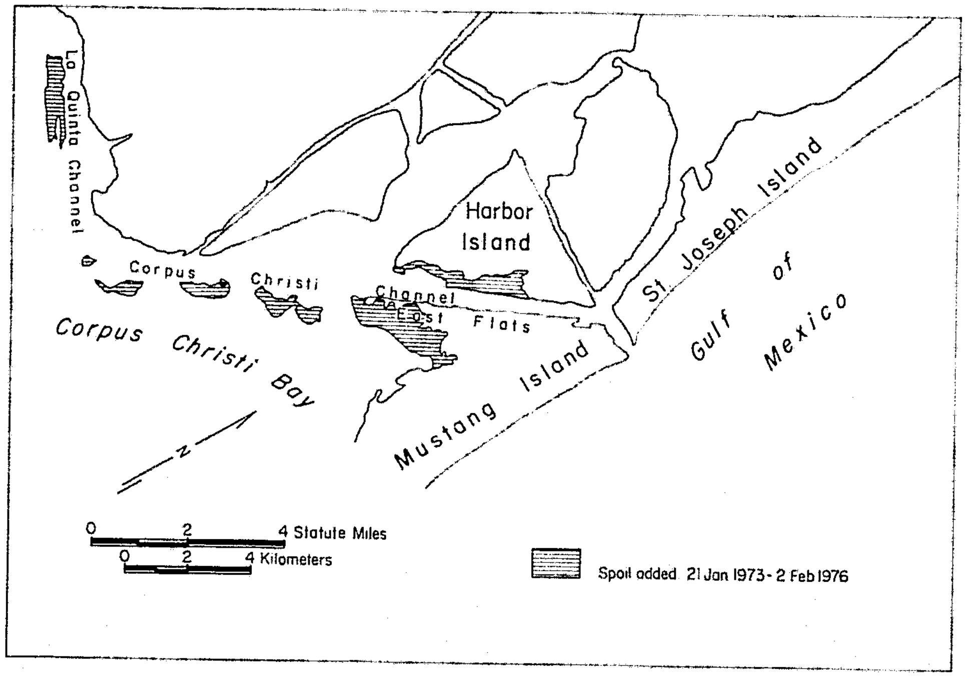


Figure 4. Comprehensive Summary of all Spoil Disposited Along the Corpus Christi and Aransas Channels between 21 Jan. 1973 - 2 Feb. 1976.

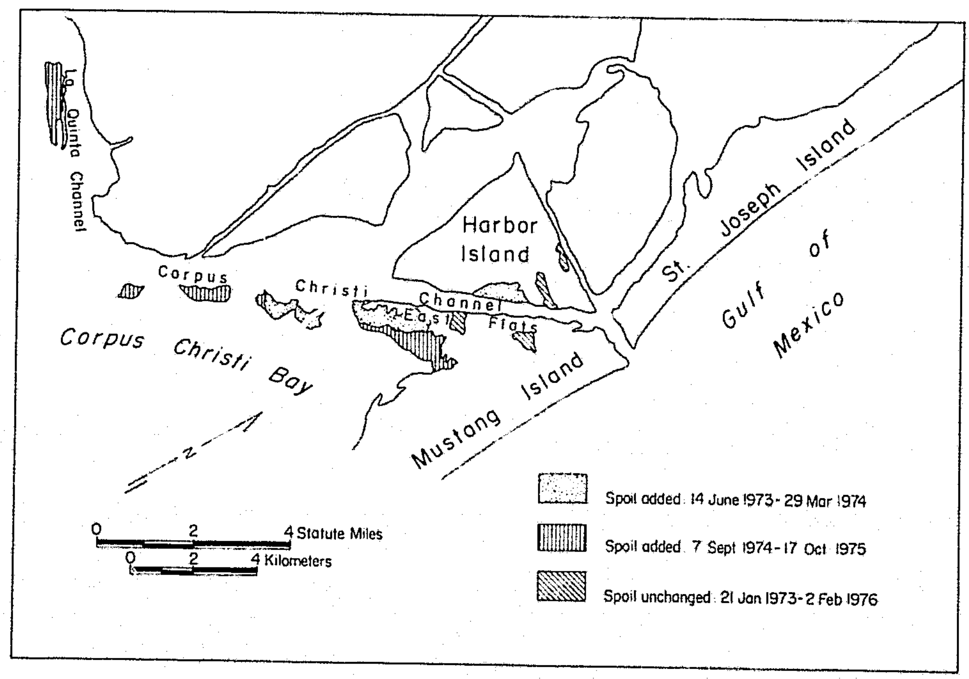


Figure 5. Chronological Distribution of Spoil Disposited Along the Corpus Christi and Aransas Channels.

photography and enlarged sections of the image interpretation map. This procedure was sufficient to determine that some of the resulting classes could be directly related to the classification scheme and that, in other cases, various combinations or "splitting" of classes was required to improve the correlation. For the first three test sites, no effort was made to compare the computer-generated map classes from one Landsat scene to those of another scene covering the same site, nor to standardize the symbols used on the line printer maps.

For Site 4, development and use of the change detection program, DETECT (described in section 3.4), required (1) detailed correlation of classes displayed on the computer-generated maps from each scene which were to be compared for change detection and (2) the use of standard symbols. Consequently, the 1:24,000 scale maps generated from the four Landsat scenes covering Test Site 4 were compared in detail with aerial photography and the classification scheme, and classes were combined to fit as nearly as possible with that scheme. Results indicated that all of the Level I land cover and land use classes could be identified easily on the computer-generated maps, as well as the water and most wetland classes, which were attempted at Level II or Level III. However, the four Urban or Built-up Land classes, the four Barren Land classes, and one of the Wetland classes (Vegetated Dredge Spoil) were not distinguished on these maps. As a consequence, a classification scheme was adapted for the computer-assisted analysis of Landsat scenes, as shown in table 4.

Table 4.

LAND COVER AND LAND USE CLASSIFICATION
FOR USE WITH LANDSAT COMPUTER COMPATIBLE TAPES

		Printer Symbols
1	Urban or Built Up Land	]
2	Agricultural Land	#
3	Grassland/Rangeland	\
4	Forest Land	&
5	Water	
	Non Turbid	G
	Slightly Turbid	A
	Moderately Turbid	Z
	Highly Turbid	=
6	Wetlands	
	Topographically High Marsh	X
	Topographically Low Marsh	>
	Tidal Flats	%
	Sea Grass/Algae	Δ
7	Barren Undifferentiated	'

It is likely that, by continued correlation with ground truth data and subsequent refinement of the various land use and land cover classes, additional classes can be mapped using the computer-assisted techniques. However, it was realized from the outset of this investigation, that classes derived by computer-assisted techniques, using only spectral information, might not precisely correlate with those delineated using the image interpretation techniques, since both spectral data and other information are used by the interpreter. As an example, Beaches, Dunes, and Barren Dredge Spoil in a given area usually contain identical computer classes from the analysis of spectral data alone, but can be differentiated on Landsat images and computer-generated displays when shape and association with other features are considered.

Analysis of spectral characteristics alone can produce a large number of classes, typically 30-40 in a single 7.5 minute quadrangle. Difficulty lies in grouping these classes into a scheme which will provide the most useful information. This investigation began with a classification scheme which was clearly designed for human interpretation, and was subsequently adapted to the computer-assisted techniques. The result is that essentially a Level I classification only was derived by computer techniques, with some finer detail in one or two categories. For application of computer techniques to future projects, a classification scheme designed to optimize spectral characteristics could provide more detailed displays, that are just as meaningful to the user, than is possible from the current classification schemes.

3.2.3.2 Correlation Procedures

Correlation of computer results with "the real world" requires the use of various types of supportive data to verify the validity of computer-assisted classification results. In addition to aerial photography, results of the following procedures have been included as supportive data:

HGROUP

The HGROUP results (see Harwood, et al., 1976, section 3.5, p. 15) provide assistance in determining what classes might be combined (based on the spectral similarity of mean values) to fit the desired classification scheme (fig. 6).

Mean Plots

Graphically depicting the four channel statistical means of all generated classes aids considerably in the correlation task. Both similar and unique classes can be identified (based on the knowledge of typical vegetative, soils and water reflectance curves) by noting curve shapes and intensity (fig. 7). Subtle class differences, such as water of relative degrees of turbidity, can also be discriminated.

3.2.3.3 Progress In Computer-Assisted Analysis

The analysis of Landsat computer-compatible tapes (CCT's) was initiated in the order of assigned scene number (table 1), using the same classification parameters for all four scenes (table 5). The revised sequence of steps used in the analysis is shown in

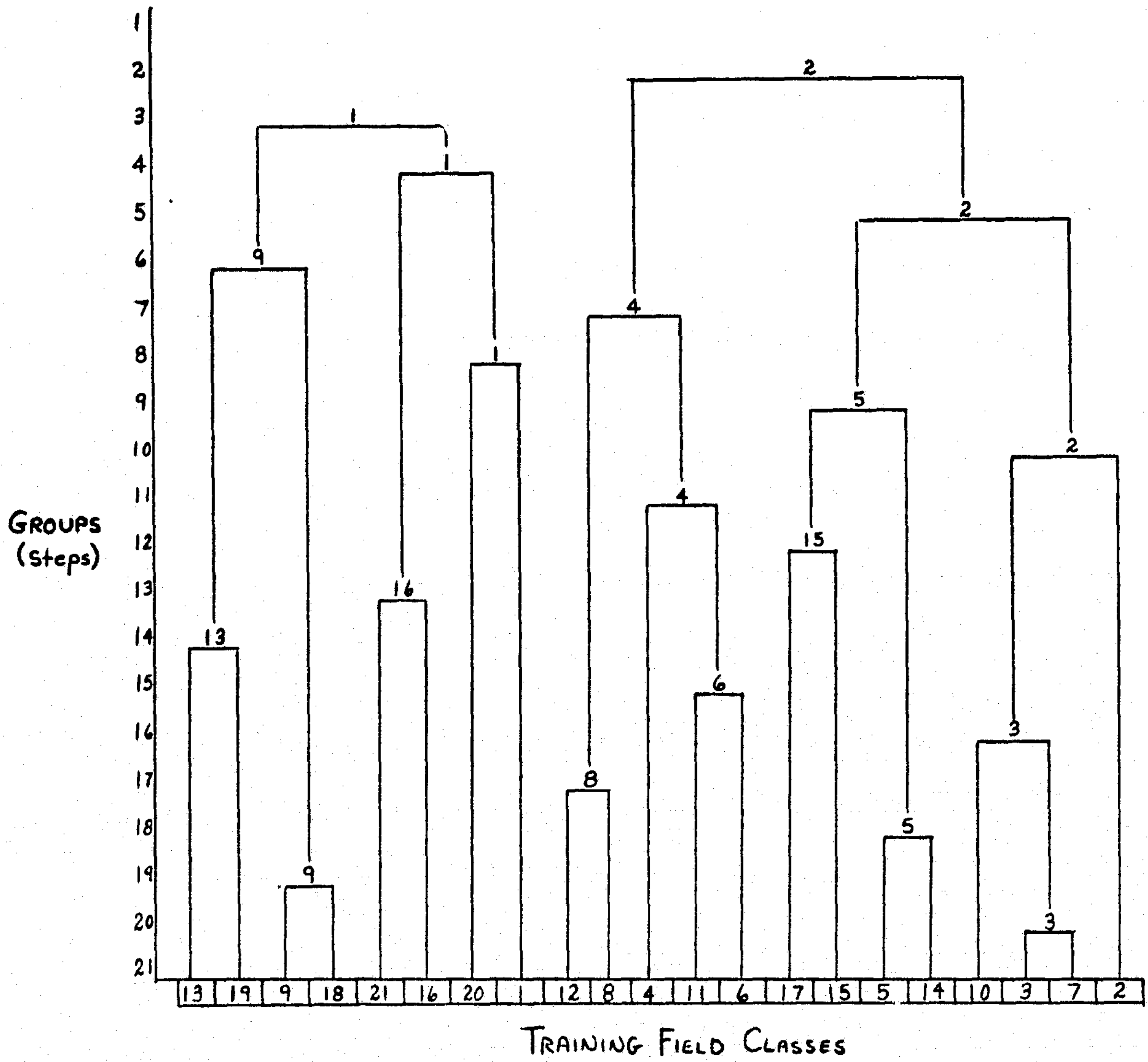


Figure 6. Stepwise Hierarchical Tree Derived from HGROUP

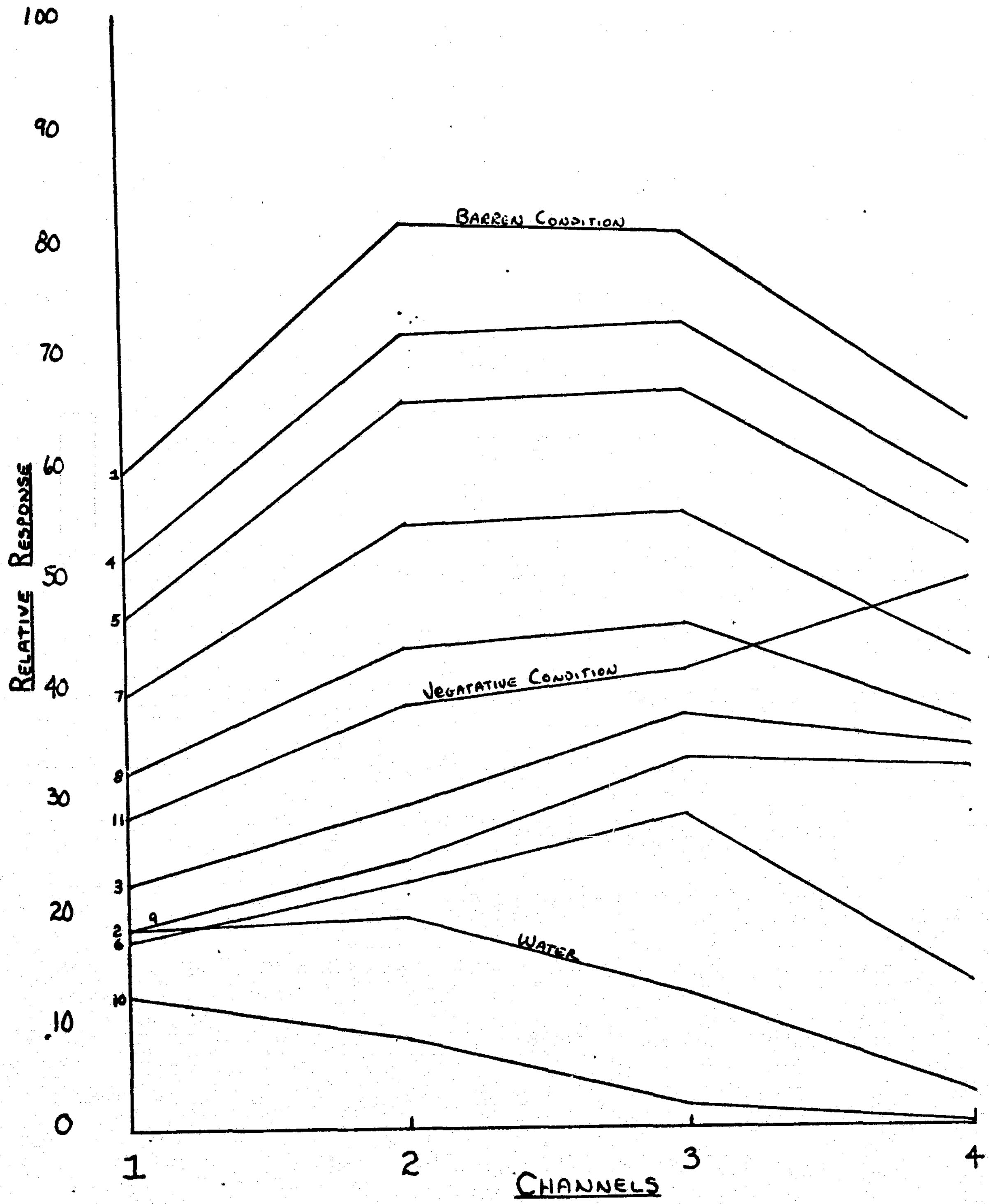


Figure 7. Plot of Spectral Means Derived from ISOCLS Results

table 6. A discussion of problems and adjustments to the classified data for each scene to provide the four land cover and land use maps with 10-13 computer classes (table 4) is summarized in Appendix B.

Table 5.

LARSYS/ISOCLS PARAMETERS

Number of Channels Used - All four channels

Number of Iterations - 10

Minimum Number of Points Per Class - 20

Minimum Separation Between Class Means - 2.0

Maximum Standard Deviation - 3.0

Maximum Classes - 50

3.2.4 Evaluation of Classification Accuracy

3.2.4.1 Accuracy of Image Interpretation Products

To evaluate the classification accuracy of Landsat maps of the Harbor Island test site, a comparison of selected locations was made with aerial photography. A spatially stratified random sample (Berry and Baker, 1968; Wood, 1955) of points within the land area of each Landsat map was obtained using a random number table and a one-inch grid. This corresponds to 2-by-2 mile (3.2 x 3.2 km) spacing at the map scale. Subdivisions representing 0.2 x 0.2 mi. (0.32 x 0.32 km) spacing within each grid block were established, and two points were randomly selected from within the four mile-square (10.24 km^2) area represented by each block.

Table 6.

STEPS IN COMPUTER-ASSISTED ANALYSIS OF LANDSAT DATA

Scene ID:

Test Site:

Description:

1. Select Landsat scene and determine data tape ID number.
2. Exame available imagery.
3. Merge data tapes or duplicate tapes if necessary.
4. Estimate scan line and sample numbers for the areas of interest.
5. Generate grayscale maps of the area. (GRAYMAP/PICOUT)
6. Obtain meteorological data.
7. Participate in orientation field trip.
8. Establish control network (COEF).
9. Classify water using DAM.
10. Cluster all training areas within the scene (ISOCLS).
11. Examine class statistics.
12. Refine a training class if indicated by previous steps.
13. Use class statistics to build the look-up table (ELLTAB TABLE).
14. Combine subclasses for display purposes (HGROUP).
15. Classify the area (ELLTAB CLASSIFY).
16. Register and display the classified results (REGISTER).
17. Outline or color code homogenous areas.
18. Examine the classification map (Correlate with ground truth data).
19. Stop if satisfied with the results.
20. Retrain on unclassified or poorly separated areas (ISOCLS).
21. Go to step 12.

NASA aircraft photography, acquired for February and October 1975 at scales of 1:120,000 and 1:30,000, and supplemented by environmental geologic and land use mapping (Brown, et al., 1976) were used to interpret land cover and land use for these locations. Each point was considered to represent a circle three Landsat pixels, or 0.24 km, in diameter on the ground. The analysis was done by an interpreter who had not been involved in classification of the Landsat data. Both color and color-infrared films were available, as were facilities for stereoscopic viewing.

Results of the accuracy analysis are shown in table 7. Since the combined information content of the aerial photography and the published maps far exceeds that of the Landsat imagery, these data were considered valid sources of ground truth. Points which could not be classified as to land cover/land use after examination of 1:30,000 aerial photography were placed in a questionable category. No field checking of these locations was attempted; therefore, this accuracy analysis represents only a comparison of Landsat imagery with medium-altitude photography.

Taking all three scenes (table 7) together, a mean accuracy of 84.0 percent is indicated, assuming one-half of the questionable points are considered correct. This compares favorably with the 85 percent minimum level of interpretation accuracy suggested by Anderson, (Anderson, et al., 1976) as a criterion for evaluating land cover and land use classification systems. While range-pasture land was most accurately mapped (97.1 percent), undifferentiated barren areas and tidal flats were least accurately delineated (60.0

Table 7.

ACCURACY ANALYSIS OF LANDSAT IMAGE INTERPRETATION
MAP PRODUCTS, HARBOR ISLAND TEST SITE

	Number of Points Checked			
Scene	Correct	Questionable	Incorrect	Accuracy[1]
25 Feb. 1975 (2034-16202)	74	11	8	85.5%
10 July 1975 (5082-16080)	69	7	10	84.30%
2 Feb. 1976 (2376-16172)	59	10	9	82.1%

[1] Percentage accuracy computed by assuming that one-half of the questionable points would ultimately be considered correct, which will be the computation method used unless otherwise stated.

and 62.5 percent, respectively). One-third of the undifferentiated barren areas termed incorrect and questionable could be correctly identified as urban areas on the photography. High reflectance common to both categories contributes to this confusion. Tidal flats possess gradational boundaries with submergent seagrass and areas of algal mat, and hence can be difficult to delineate, especially at higher water levels. Figure 8 summarizes the interpretation accuracy for all categories in the Harbor Island Test Site.

3.2.4.2 Accuracy of Computer Classification

The accuracy of the computer-assisted classification was evaluated by adapting the method used for determining the accuracy of the image interpretation products. Points selected for evaluation of the image interpretation maps were located on a clear plastic enlargement of the image interpretation line boundary map at a scale of 1:24,000. This enlargement was then matched to the computer-assisted classification display. Points on the overlay were assumed to be located within four classification pixels or an area of about 200 meters on a side. The pixels were compared to the the image interpretation and then to 1:30,000 aircraft photography to determine which category was represented under each point. Results were tabulated in a matrix such as the one shown for the 25 February 1975 scene in table 8.

computed by adding the points in the diagonal zone in table 8, and dividing by the total number of points sampled. For the 25 February 1975 scene, the overall accuracy of the computer-assisted classification, comparing Level I categories, was 60% but decreased to 48%

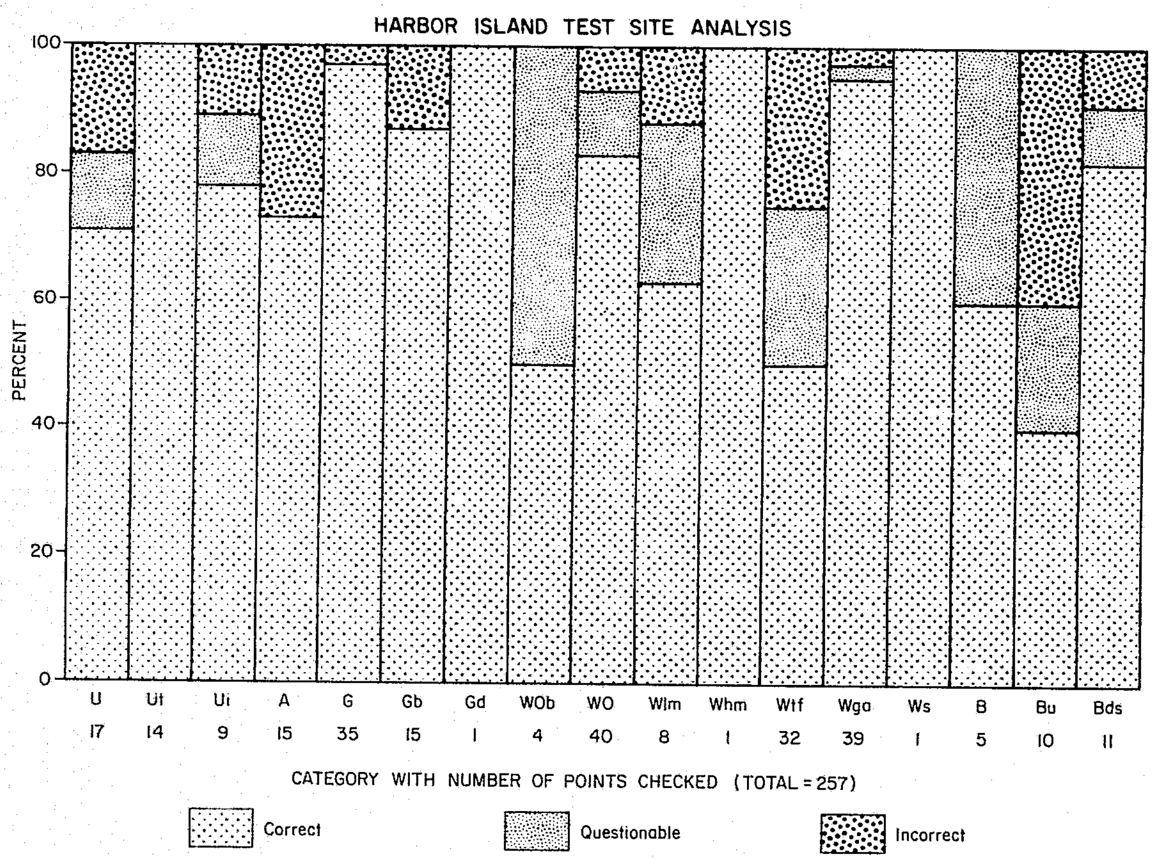


Figure 8. Summary of Interpretation Accuracy for all Categories in the Harbor Island Area Test Site.

Table 8.

MATRIX SHOWING DISTRIBUTION OF COMPUTER CLASSIFICATION RELATIVE TO IMAGE INTERPRETATION OF LANDSAT DATA

Image Interpretation-Level I Classes

Computer Classification-Level I Classes

	Urban	Agric.	Grass	Wood	Water	Wetland	Barren
Urban	2/12%	0	0	0	0	0	2/20%
Agric.	0	2/67%	0	0	0	0	0
Grass	7/41%	0	14/88%	10/77%	0	1/4%	3/30%
Wood	1/6%	1/33%	1/6%	3/23%	0	1/4%	1/10%
Water	0	0	0	0	0	0	0
Wetland	6/35%	0	0	0	0	25/88%	0
Barren	1/6%	0	1/6%	0	0	1/4%	4/40%
Total No. of computer points in each image interpretation class	17	3	16	13	0	28	10

for Level II and III categories. Overall accuracy for scenes 1-3 is summarized in table 9.

The low overall accuracy of the computer classification, compared to the image interpretation, is influenced by a number of factors. The most fundamental and obvious difficulty relates to the classification scheme being utilized. The land cover and land use scheme used in this study, as well as that developed by Anderson (Anderson, et al., 1976), relies on the image interpreter applying a whole range of characteristics--color, tone, shape, size, texture, and association with other features--to map different categories. The computer analysis of Landsat Imagery can use only one characteristic: the color (i.e., the spectral reflectance) of the category being mapped. Thus, it is unlikely that the computer could classify the Gulf Intracoastal Waterway, for example, as an urban-transportation category instead of a water category. It might, on the other hand, be able to classify the canal water according to relative turbidity. Similarly, barren beach and a barren dredge spoil consisting of the same material probably cannot be differentiated on the basis of spectral data alone.

Another factor in this particular study which probably accounts for some of the lower accuracy in the computer classification is that the final computer-generated product was not completely refined to the greatest extent possible due to time constrainst in completing the project. For example, the computer classification of both winter scenes identified some agricultural muds in Redfish Bay, a water area that contains primarily shallow water and seagrasses.

Table 9.

ACCURACY ANALYSIS OF LANDSAT COMPUTER-GENERATED MAP PRODUCTS, HARBOR ISLAND TEST SITE

Scene	Number of Points Checked	Number of Points Which Correlated to Aerial Photography	Accuracy
25 February 1975 (2034-16202)	87	52	60%
10 July 1975 (5082-16080)	89	54	61%
2 February 1976 (2376-16172)	74	48	65%
TOTAL	250	154	62%

Fallow agricultural fields on the mainland were mostly classified as agriculture but included some areas of marsh and seagrass symbols. Thus, additional statistics possibly could be generated to better separate the agricultural and seagrass areas into distinct spectral classes.

3.2.5 Application of Landsat Products to Management Activities

3.2.5.1 Objectives for the Site 4 Test

During the period for which Landsat data were available (1973-1976), numerous projects and activities were proposed and initiated in this test site that concern the General Land Office in managing coastal public lands. Five of these activities, listed in table 10, were used to select four local areas within the Harbor Island test site for comparing classification results of the Landsat Scenes (fig. 9).

These activities are examples of some recurrent issues and problems encountered in managing coastal public lands in Texas. Information needs typified by these examples were used to help formulate investigation objectives for this test site, and to provide a basis for evaluating the utility of the Landsat-derived classification products in the Harbor Island area.

The objectives were:

1. To define the shoreline boundaries of tidal flats, bay margins, and marshes at different tidal stages.
2. To describe the growth of spoil islands along ship channels and other disposal sites for evaluating the disturbance

Table 10.

EXAMPLES OF MANAGEMENT ACTIVITIES AND ISSUES
IN THE HARBOR ISLAND AREA OCCURING BETWEEN 1973 AND 1976

Area	Activity	Action Required	Specific Information Needed
1	Oil and Gas leasing in Redfish Bay	drilling recommendations prior to lease sales	location of seagrass areas, existing channels and adjacent environments for alternative drilling locations
2	Proposed site for inland deep port at Harbor Island	lease of state lands for spoil deposition	location and acreage of existing spoil, marshes and seagrasses within proposed lease area
3	Proposed resort development on Mustang Island	easement for access channel to marina	location of state/private boundary (mean high tide) on tidal flat
2,4	Enlargement of Corpus Christi and LaQuinta Ship Channels	proposed lease of additional state land for spoil deposition and turning basin	location of existing spoil areas and wetlands
4	Potential site of regasification plant for imported liquified natural gas (LNG)	potential lease of state land for boat dock, piers, etc., and review and comment on permits required from other agencies	adjacent land cover and land use conditions especially wetlands

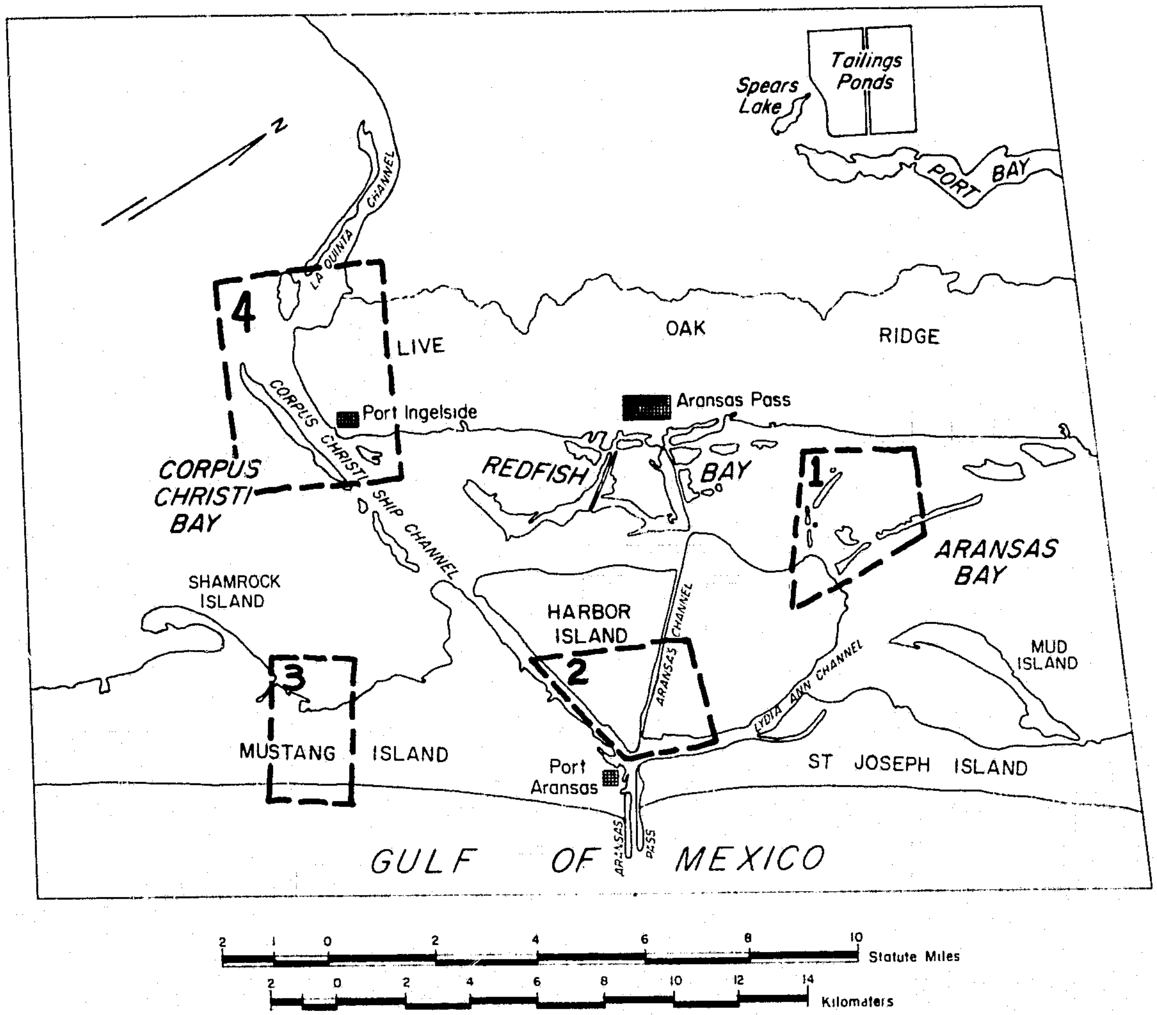


Figure 9. Location of areas within Harbor Island area test site for comparing classification results of Landsat scenes.

of wetlands and bay margins.

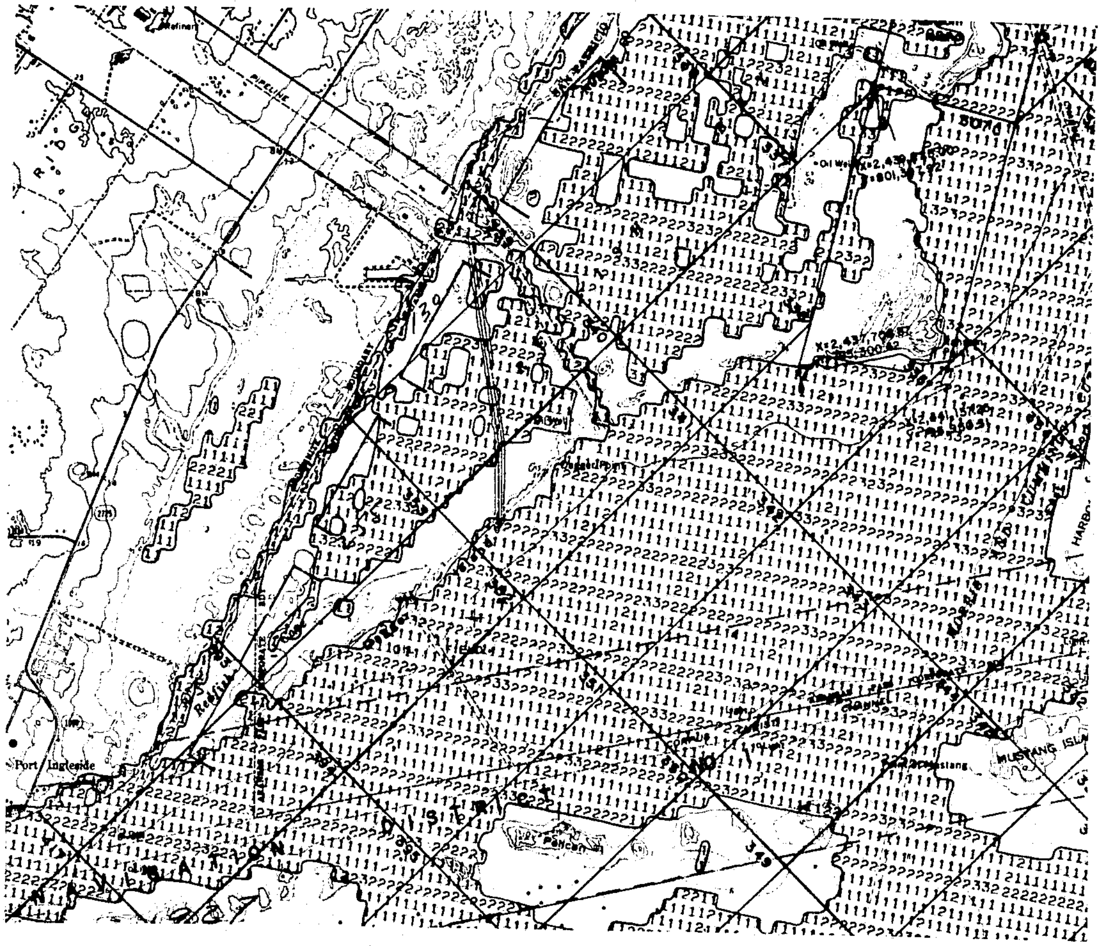
3. To describe the distribution of, and changes in, land cover, including wetlands, within the test site for information on future uses and potential impacts of such uses on coastal public lands.

The land cover and land use classification products derived from both Landsat images and computer compatible tapes (CCT's) were used as the basic information source for evaluating the usefulness of Landsat data in providing the information listed above. The land/water boundary displays, generated from the computer compatible tapes by using the Detection and Mapping (DAM) package, also were used for locating water within tidal flats and marshes.

3.2.5.2 Information from Landsat Products

Inundation of Tidal Flats, Marshes, and Bay Margins - Overall results of the evaluation indicate that the use of Landsat products for detecting the distribution of inundation of tidal flats, marshes, and bay margins is quite satisfactory. Tide gages recorded low water levels for the 25 February 1975 and the 2 February 1976 scenes due to the passage of polar cold fronts with strong northerly winds prior to the satellite pass. Water levels were higher at the time of the 10 July 1975 scene. Effects of these differences, which may have represented about one foot (30 cm) or more of water depth at various places in the scene, were very evident on the classification products; and were especially striking on land/water maps generated by the DAM package when used with overlays showing state ownership and USGS topographic and cultural information (fig. 10).

2/2/76



Low Tide

Figure 10. Portion of test site as depicted on the detection and mapping (DAM) display (National Aeronautical and Space Administration 1976) with an overlay showing the numbered state-owned land tracts and USGS topographic information.

At low tide, on the 25 February 1975 and the 2 February 1976 scenes, very shallow areas in Redfish Bay (areas 1 and 4, fig. 9) and on the bay side of Mustang Island (area 3) were classified by image interpretation as a mixture of tidal flat and seagrasses. When the winter scenes are compared to the high-tide 10 July 1975 scene, the tidal flats in these same shallow areas tended to shrink and be replaced by seagrasses and algal flats, or water. For example, in area 3, on the back side of Mustang Island, the tidal flat area appeared to shrink from about 1 mile (1.6 km) in width to slightly more than one-half mile (0.8 km) with a seagrass/algal flat zone appearing on the bay side. In areas 1 and 4 in Redfish Bay, with the higher tide, water classes replaced tidal flats and reduced the areas classified as seagrasses.

For the study of tidal shorelines, a library of Landsat scenes correlated to known water levels from Corpus Christi and Redfish Bays might be useful to supplement information gathered from visual observations and tide gage data regarding the areal extent of inundation over large areas at known water levels. Such historical records of inundation are not now available for bay shorelines in Texas. Although these records could not replace ground surveys and tide gages for determining legal boundaries, they could be used to estimate shoreline boundary locations for management purposes, without additional ground surveys. For example, boundary questions concerning the activities listed in table 10 for areas 2, 3, and 4 (fig. 9) could have been supported by using a Landsat computer classification product and depicting water levels at about mean high tide with a clear plastic overlay showing state-owned tracts on a USGS topographic base at 1:24,000 scale. This is a situation where the scaled and registered computer classification has a distinct advantage over the image interpretation map, even though the overall classification accuracy of the computer classification display might be much lower.

Although precise boundaries were not detected between land and water classes (due to the pixel size of about 1 acre), the Landsat classification products were sensitive to the effects of water level changes and can be used to demonstrate the general areal extent of inundation when compared to low water conditions.

Spoil Islands - Locating and monitoring spoil areas is important because channels for navigation and commerce in Texas bays require continuous maintenance dredging. Because of the long-term commitment to maintain these channels, more and more state-owned submerged lands and wetlands will be required for use as disposal sites. In the Harbor Island Area, progress in enlarging the Corpus Christi and LaQuinta Ship Channels (areas 2 and 4, fig. 9) could be documented by the growth of adjacent barren spoil islands on both image interpretation (section 3.2.2.2) and computer classification products. Wetland classes in the vicinity of these channels and the proposed deep water port (area 2) also could be located and identified well enough to locate potential sites for future spoil disposal, thereby avoiding areas containing seagrasses or marsh tation. It is important to recognize that information from Landsat would supplement other data sources by providing a temporal history of change from dredging and spoil disposal, as well as providing a current picture with which to review proposed projects. More detailed information on wetlands, for example, could be obtained, when needed, from sources such as existing aerial photography and the Environmental Geologic Atlas Of The Texas Coastal Zone (Brown, project coordinator, in progress).

Examination of available Landsat products indicated that information for monitoring existing spoil disposal sites, and the identification of wetland types to review proposed disposal sites, were best provided by the image interpretation products for the following reasons:

1. The 1:125,000 scale is convenient for examining large areas, such as the entire route of the ship channel.
2. Precise registration of the data to quadrangle maps is not necessary for initial review of projects.
3. Landsat standard products in Bands 5 and 7 can be readily used for detecting changes in spoil areas without more time-consuming analysis.
4. The 80 percent accuracy of the dredge spoil category inspires confidence in the use of image interpretation products (fig. 8).

Land Cover Conditions and Changes - Qualitative evaluation of the Landsat-based map products indicated significant variation in the boundaries of certain classes. The urban class presented a problem in that the class boundaries differed on each scene for both image interpretation and computer products. The low-density urban areas within the Harbor Island Test Site have a spectral response derived from a mixture of barren areas (structures, pavement, etc.), cultivated vegetation, such as lawns and shrubs, and some natural vegetation. This mixture creates a spectral and textural contrast with the surrounding area which can be detected during analysis of the images. The contrast can be quite subtle along the margins of the urban areas where quality of the data, growth stage of the vegetation, and for image interpretation, the subjective decisions of the interpreter, determine boundary placement. Differences in atmospheric conditions and sun angle between winter and summer scenes also influence category delineation during image interpretation and computer classification.

The success achieved in identifying land cover conditions and monitoring changes from Landsat data depends on the accuracy and consistency of the classification results. While the consistent delineation of urban areas has not been achieved, wetlands, grasslands and water have shown greater consistency from scene to scene and between analysis methods. For uses where the smaller 1:125,000 scale was adequate, the image interpretation product was preferred over the computer product because a more informative classification scheme (table 3) was used, and the overall accuracy was higher (section 3.2.4). The computer-assisted classification products does, however, have the advantage of insuring that no data are overlooked. For example, a small area of vegetation on a spoil island was not visually mapped from the imagery but was delineated by the computer analysis as grassland vegetation. While the image interpreter may have mapped the entire area as barren dredge spoil, the computer made a correct classification on a spectral basis by delineating a small area of grassland. Note that where larger, 1:24,000 scale data are required the computer-assisted product can satisfy this need, whereas image interpretation products contain too much distrotion for useful enlargement.

3.2.5.3 Summary of Findings

1. For the study of tidal shorelines, a library of Landsat scenes would be extremely useful to supplement information gathered from visual observations and tide gage data regarding the areal extent of inundation over large areas. Such historical records of inundation are not now available for bay shorelines in Texas. Although these records could not replace ground surveys and tide gages for determining legal boundaries, they could be used to estimage shoreline boundary locations for management purposes without additional ground surveys.

2. Monitoring spoil areas is important because navigation channels in Texas bays require continuous dredging, and more and more state-owned submerged lands and wetlands will be required for use as spoil disposal sites.

3. Progress in enlarging the Corpus Christi and LaQuinta Ship Channels could be documented by the growth of adjacent barren spoil islands, detected on Landsat images.

4. In addition, wetland areas in the vicinity of these channels could also be located and identified well enough to locate potential sites for future spoil disposal, thereby avoiding areas containing seagrasses or marsh vegetation.

5. For uses where the 1:125,000 scale maps were adaquate,

the image interpretation product was preferred over the computer product because a more informative classification scheme was used, and the overall accuracy was higher.

6. Computer-assisted classification products do, however, have the advantage of insuring that no data are overlooked. For example, a small area of vegetation on a spoil island was not visually mapped from the imagery but was delineated by the computer analysis as grassland vegetation using spectral data only. Such vegetated spoil islands often become important rookeries for coastal birds and are protected by the State.

7. Where 1:24,000 scale maps are required the computer-assisted product can satisfy this need whereas image interpretation products are not adequate.

8. In addition, the computer display is scaled and registered to USGS 7.5 minute topographic maps. This registered display is an advantage when used with a series of plastic overlays, prepared at a scale of 1:24,000 and showing state-owned coastal lands, because correlation with existing map data is improved.

3.2.6 Progress of Cost-Savings Evaluation

In the contract between NASA and the General Land Office, both parties agreed upon a cost-benefit study as one of the methods by which maps derived from satellite data should be evaluated. In the summer of 1975, various methods of economic evaluation were reviewed and an approach for extracting cost data from the Landsat Project was designed. These findings were documented in Appendix G of the September 1975 Quarterly Report, (Jones, et al., 1975a), which reviews the pros and cons of a cost-benefit study and possible alternative methods of evaluation. Appendix C of that report describes a simple cost-accounting system which was utilized this summer and fall by participants in the project, the information from which is expected to be the basis of the cost-benefit study.

Of the various analytical techniques discussed in the September report, a cost-saving methodology was chosen for this project. Given limitations of time and information, this type of study seems most suited for evaluation of Landsat map products at the present time. A cost-saving framework can be thought of as a form of cost-benefit. Such an analytical approach assumes that all products are of the same value to the decision-maker. For example, the same benefits are assumed to accrue from the use of maps constructed from essentially different imagery or in different ways. The question of choice among alternatives is then reduced to one of the least-cost method of mapping. Benefits are assumed to be the same.

In the Landsat Project, a comparison of costs is being made among three methods of producing a land cover and land use map with categories agreed upon by Landsat participants (tables 3 and 4). The three methods of mapping are: computer-assisted classification utilizing Landsat digital tapes, direct optical image interpretation utilizing Landsat imagery, and interpretation utilizing conventional aerial photography. None of the three resulting map products can be expected to yield the same type of map in terms of classes, detail, accuracy, or consistency. In addition, the timeliness of information--that is, the rapidity by which a completed map product can be delivered to a user, given a required level of confidence in the resulting product--will also differ. These are all dimensions in addition to costs which must be taken into account by users of the product.

These "benefit" differences--that is, differences deriving from the utility of the product to users--will not be incorporated into the economic portion of the study, for the cost-saving approach adapted for this study views these map products as having the same value to decision-makers and evaluates their differing costs only. Other sections of the report will evaluate these differences in quality as part of the overall objective of the Landsat Investigation.

Design of the Cost-Saving Study

The cost of computer-assisted classification and image interpretation map products will be based on time sheets being kept on actual working experience during interpretation. These records on four different scenes of Site 4 (Harbor Island Test Site) will yield an average cost figure for interpretation. Experience of the preceding year has been oriented toward development and refinement of techniques. This summer was selected as the period during which actual procedures were tested for reliability. Testing of procedures will approximate the nearest possible estimate of actual interpretation time required to produce the land cover and land use maps. The time sheets for staff and equipment can in turn be utilized to convert staff salaries and equipment costs, as well as other costs, into cost per square mile for mapping. Such costs will have to be compared with qualitative measures to yield a total picture of the comparative advantage of computer-assisted and "visual" interpretation techniques.

Cost of producing a map product similar to that of maps derived from satellite imagery, but utilizing conventional photography, is being provided courtesy of the Bureau of Economic Geology. A questionnaire has been designed which was aimed at gathering costs of previous mapping experience at the Bureau. Several possible maps exist for which there were budgetary data; in addition, personnel who did the mapping were available for consultation. It would have been desirable to obtain a land cover and land use map similar to that being produced by the Landsat participants, but this was not possible. This does not detract significantly from cost estimates, though, because Bureau experience indicates that the number of classes may be the major factor in interpretation costs. A map having from 15 to 25 classes was requested, a range broad enough to encompass several maps the Bureau had done, and close enough in number to the 23 classes of the Landsat Project.

Costs have been broken into three major classes, or stages of production: data acquisition (costs of obtaining imagery), data interpretation (preliminary data collection and field research through hand-color preparation for press), and data display (editing of hand-colored copy and production of the "hard copy" color display). Data interpretation was further broken down in steps for the computer-assisted technique (table 6) and "visual" interpretation (Jones, et al., 1976, table 3, p. 24). A complete list of the information necessary to compute costs for the Landsat products is shown in table 11, undifferentiated by computer or "visual" techniques. The questionnaire requesting information on costs of mapping in the Bureau of Economic Geology is shown

Table 11.

INFORMATION FOR COMPUTING COSTS OF ADP INTERPRETATION AND IMAGE INTERPRETATION, BY TASKS, OR STAGES OF PRODUCTION.*

Task 1. Data Acquisition.

-Compute time by steps in December, 1975 Quarterly Report.

-Time in hours of use of special equipment.

-Time in hours by staff level.

Task 2. Data Interpretation.

-Compute time in Tables 2 and 3.

-Time in hours of use of special equipment (including computer time).

-Time in hours by staff level.

-Travel costs.

Task 3. Data Display

-Commercial costs of display.

-Time to order hard copy, color map.

General Information For All Three Tasks:

-Costs of office space, equipment and supplies.

-Salary and fringe benefits by staff level.

-Cost and life of special equipment.

*See Appendix C in the September, 1975 Quarterly Report for a descirption of the Cost Accounting System.

in table 12.

3.2.6.1 Major Objectives and Limitations of the Study

Information from the Landsat cost-saving study represents a "first cut" in the evaluation of map products derived from satellite data. The usefulness of the study to the state in evaluating systems delivering products from satellite data must be weighed against its limitations. It is instructive to examine these limitations in order to glimpse what a complete evaluation would entail.

First, both the computer-assisted and image interpretation map product are oriented toward one specific land cover and land use classification scheme. This scheme is as much oriented toward the experimental as the practical. While it does reflect knowledge of participants of needed information about the Texas coast, it also represents the interest of researchers in exploiting the potential of interpretation technology to its fullest.

Whether or not this specific product will satisfy particular agency needs for information is something that can be ascertained only by a survey of state user needs. Such a survey in turn can be used to indicate what modifications of the product should be attempted. Only through further investigations like this one will it be possible to compare satellite products with present methods of satisfying user needs. Again, timeliness of delivery, detail, accuracy, consistency, number of classes, and costs are all elements that must be considered.

This nascent character of Landsat products means that the cost-saving study is really illustrative, lacking the rigor and require-

Table 12.

SURVEY QUESTIONNAIRE ON COSTS
OF THE ENVIRONMENTAL-GEOLOGY MAP

Stage 1. Data Acquisition (cost of obtaining imagery)

--What scale and kind of photography was used or would be recommended if the project were done today?*

--What is the <u>current</u> cost per square mile for this photography?*

--What was the staff time in man-hours by staff level (University System) for ordering?

--What was the number of hours of usage of special equipment?

Stage 2. Data Interpretation (preliminary data and field research through hand color preparation for press)

--What were the major steps (say a maximum of four) and what is a description of them in interpretation)?

For each step:

--What is the staff time in man-hours by staff level for interpretation?

--What was the number of hours of usage of special equipment?

--What was the amount of travel and special transportation utilized?

--What would be current costs for travel for individuals (travel voucher and any rental, such as airplanes)

Stage 3. Data Display (editing of hand colored copy and production of hard copy, color display)

--What are the commercial costs of display of this product today?

--What was the staff time in man-hours by staff level for editing and ordering hard copy, color display?

General for all three stages:

For all of the special equipment, what is the manufacturing company, trade name, model number, description of use, and retail costs today of such equipment? For all staff levels, what is the range of pay (from lowest to highest step) per month today?

Sources: Costs of photography from Tobin Surveys of San Antonio, Texas.

ments of a complete study. The question at issue is whether or not an agency would choose to replace or supplement present systems of collecting information with a satellite product. The comparison with cost data from conventional interpretation provided by the Bureau of Economic Geology costs leaves the needs of users out of the picture. Yet, the principles of cost-benefit analysis presuppose comparison of the most efficient alternatives for accomplishing given ends. Without such a survey of ends or uses of map products tied to Landsat capabilities, the cost-saving study reduces to an example only.

Conceivably, the Landsat map product could replace several information sources at the present time, i.e., serve different ends in different agencies. Savings in terms of costs would then be additive, thus representing the summation of savings available to several different agencies.

Another consideration is that the land cover and land use map is one of many possible kinds of map products derivable from satellite data. Any cost estimate of this one product alone omits considerations of a system producing more than one type of product. The ultimate objective of the state, though, would be an integrated system. As for costs, such a system would imply the capacity for cost-sharing. It can be anticipated that costs such as administration and special equipment shared in common would lower the costs of each individual product.

Finally, both computer and image interpretation analyses represent different methods of interpretation which will be evaluated separately for suitability in mapping. Yet, some integration of these techniques might be appropriate for producing the land cover land use map.

In short, this evaluation is truly a first step. A more integrated evaluation is impossible at this time, though it is clear that such an approach would include at least a survey of user needs, development of a variety of map products, and examination of the economics of integrating interpretation techniques.

3.2.6.2 Preliminary Accomplishments

The above discussion of the aims and limitations of the cost-saving study should give a clear idea of exactly what the expected gains from the study are. While such thinking has been part and parcel of work so far, the bulk of time was spent in contacting information sources, collecting and reviewing received cost information, and collating the data.

The first task was ensuring an orderly method of reporting on the Harbor Island site. Steps followed by the computer effort were revised. A weekly reporting system on special equipment usage time, staff time, and computer time was instituted. It was necessary then to contact information sources outside the project, so that cost information could be collected and reviewed prior to data collation and computation that was scheduled to begin when the analyses were complete. A list of anticipated tables documenting raw data for computation of costs for image interpretation is shown in table 13. The same scheme will be followed for the computer map product. These tables only document raw data and not actual computations and assumptions for economic cost computation. The final report will contain

Table 13.

TABLES FOR IMAGE INTERPRETATION MAP PRODUCT

Table 1. Sources of information for computing costs of image interpretation map product.

Table 2. Image interpretation map product: staff salary and fringe benefits by staff level, per hour.

Table 3. Image interpretation map product: data acquisition and display, staff time by staff level.

Table 4. Image interpretation map product. Data interpretation, staff time by staff level for each scene of site four and average time for all scenes.

Table 5. Image interpretation map product, cost of Landsat imagery.

Table 6. Image interpretation map product: cost and life of special equipment.

Table 7. Image interpretation map product: total hours of use of special equipment for each scene of site four and average hours for all scenes.

Table 8. Image interpretation map product: costs and life of office equipment excluding special equipment.

Table 9. Image interpretation map product: costs of office space and materials.

Table 10. Image interpretation map product: travel costs for site four.

Table 11. Image interpretation map product: costs of hard copy, color display.

such tables, so that all assumptions and computations of the study can be followed by an interested party.

There have been several delays which pushed the original schedule back. It was originally planned that all work on Site 4 would be completed by the end of August, however, due to problems discussed in section 2.0, late October was a more realistic deadline. Such delays in analysis also meant that average costs of interpretation on Site 4 could not be computed until late October.

All the data was assembled in tables during the fall 1976, with the cost-savings analysis scheduled for completion by the end of February 1977.

3.3. Special Image Interpretation Studies

3.3.1 Tidal Inundation Study

Comparison of maps from two dates (29 March 1974 and 25 February 1975) suggests that Landsat data might be used to evaluate the extent of aperiodic inundation of marsh, tidal flat, and beach. Using line boundary maps of the Pass Cavallo area, enlarged from 1:125,000 to 1:80,000, 704.8 hectares (1,741 acres) of additional emergent area were evident on the 25 February image (fig. 11). Tide gage data supplied by the Galveston District of the U.S. Army Corps of Engineers indicate (1) a 0.43-m. (1.4-ft.) lower water level for that date when compared to 29 March 1974, and (2) a complete masking of the astronomical tide (inset, fig. 11) by a wind tide resulting from strong northerly winds preceding the time of the satellite passage (fig. 12). These data illustrate the importance of obtaining

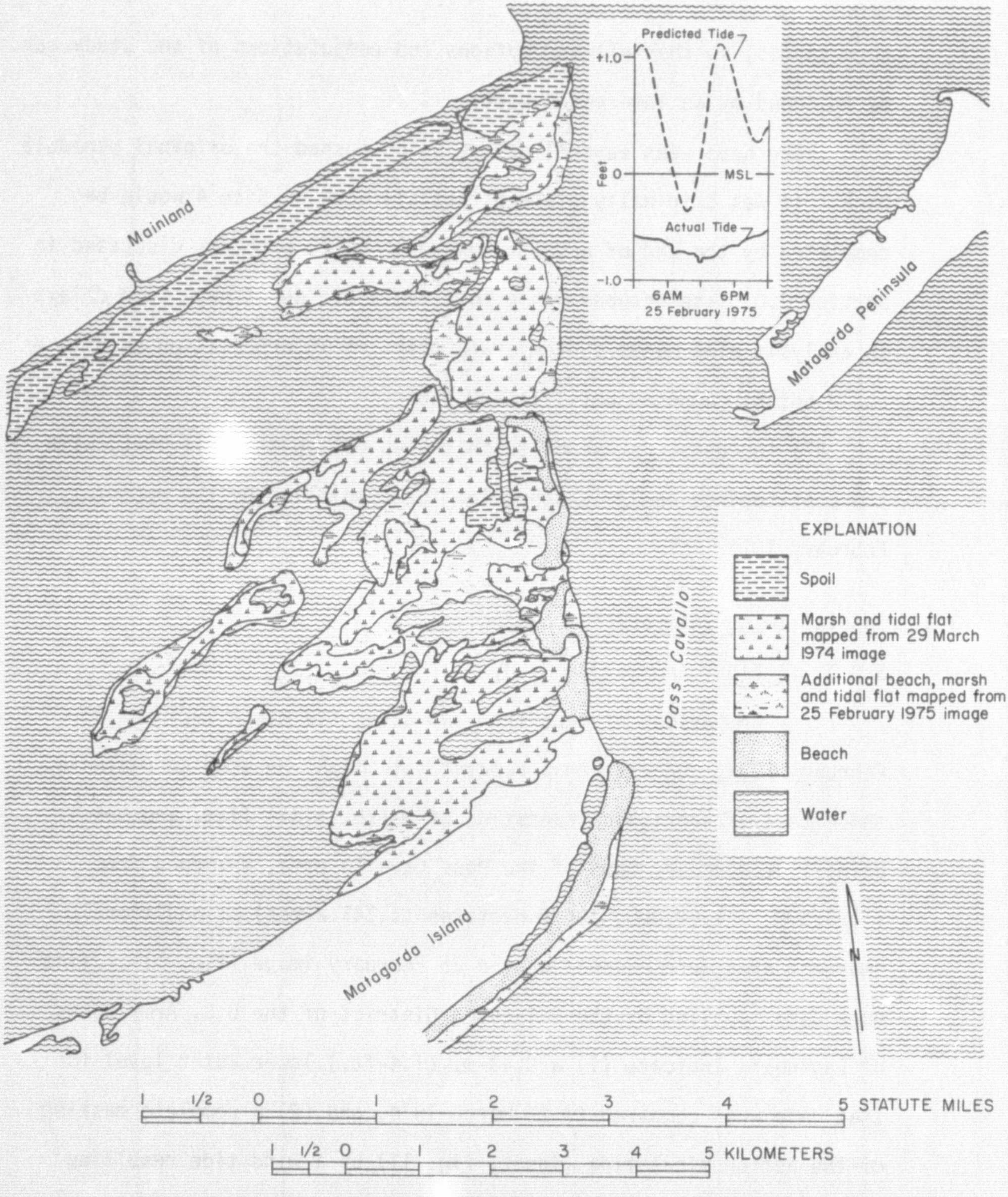


Figure 11. Map showing change in area of emergent marsh, tidal flat and beach at Pass Cavallo due to wind-tide of 25 February 1975.

time histories of wind and actual, rather than predicted, tidal elevations in evaluating water levels seen on Landsat imagery.

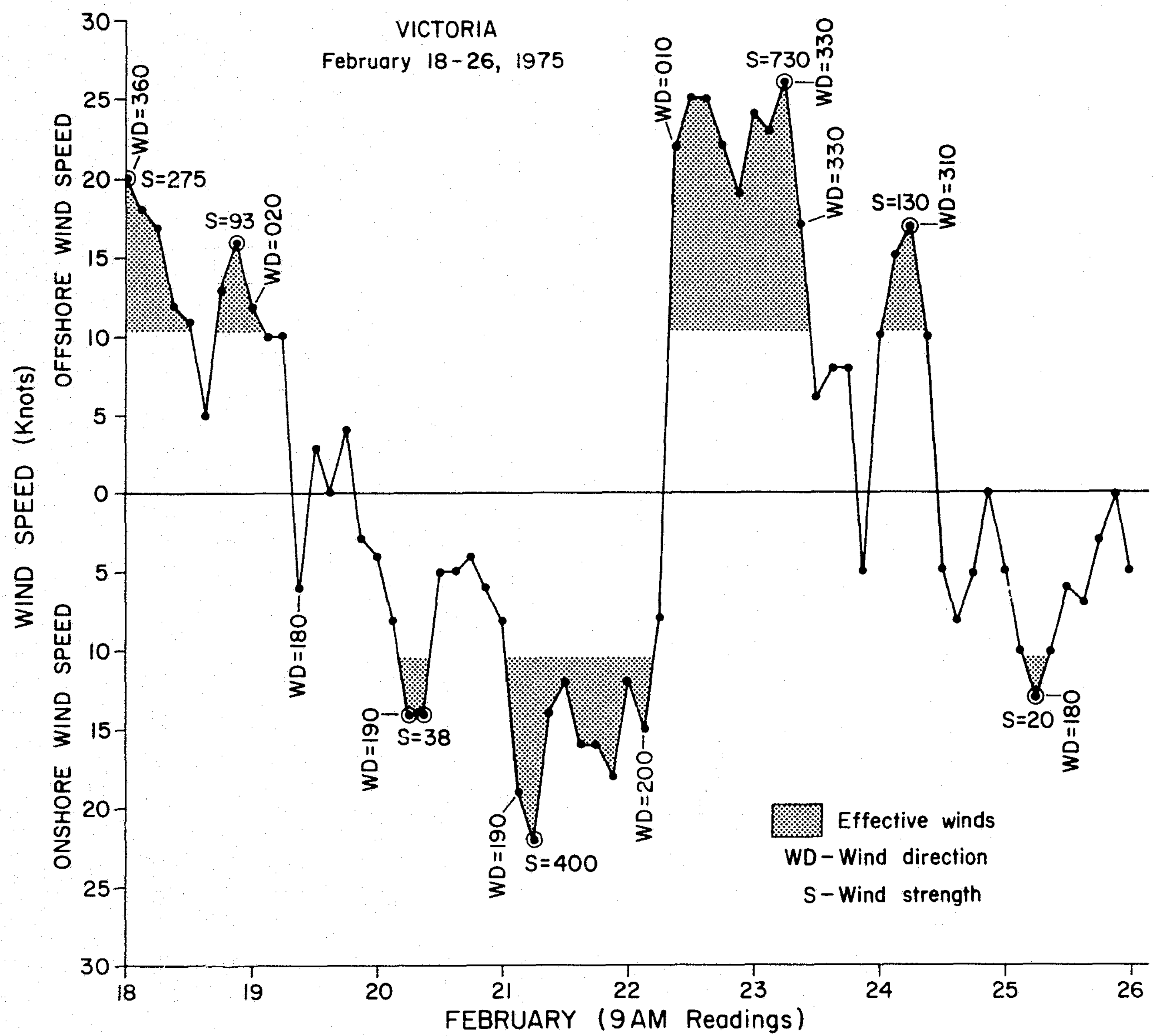
3.3.2 A Landsat Study of Turbidity and Circulation Off Aransas Pass, Texas

Landsat multispectral scanner images in the visible red band readily reveal variations in suspended sediment concentration in coastal waters (Klemas, et al., 1973, and Klemans, et al., 1974). Using this turbidity as a natural tracer, the nearshore surface-water circulation in the Gulf of Mexico off Port Aransas, Texas was examined for twenty-two scenes from 1972 through 1976. This date was correlated with tide gage records, wind velocity and direction data, wave observations, and predicted tidal current velocities.

Aransas Pass is a stablized inlet with jetties extending 1.25 km. seaward on either side. These structures control the observed turbid plumes by: (1) limiting expansion of ebb-tidal effluent to beyond the zone of inshore wave-generated turbidity, and (2) diverting inshore turbid waters seaward to be mixed with the ebb-tidal flow. Bay-derived ebb water may be as turbid or much less turbid then inshore water and, in the latter case, plumes up to 6.0 km. long result from entrainment by inlet effluent of turbid, jetty-diverted inshore water. The best developed plumes form clockwise gyres up to 8.1 km. long and correlate with the greatest tidal elevation drops (0.64 m.) and effective northerly winds. During times of weak or flood currents, only small patches of low turbidity were observed in the Gulf.

These results indicate that Landsat imagery offers a unique syn-

Figure 12. Time-history of wind data at Victoria, Texas 42 miles from Pass Cavallo, showing strong northerly winds prior to 25 February 1975. Effective winds are those above 10.4 kn (12 mph) and $S + d(v-10.4)^2$ where V + observed velocity and d + wind duration. The data are plotted at 3-hour intervals.


VICTORIA
February 18-26, 1975
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
FEBRUARY (9 AM Readings)
WD=360
S=275
S=93
WD=020
WD=180
WD=190
S=38
WD=190
S=400
WD=200
WD=010
S=730
WD=330
WD=330
S=130
WD=310
S=20
WD=180
Effective winds
WD - Wind direction
S - Wind strength

optic overview from which the circulation of inlet effluent and jetty-diverted inshore waters can be inferred. Such data could supplement more conventional data in the planning of environmental impact studies at sites of hydrocarbon production and transportation.

3.4 Changes in the Computer-Assisted Classification Program

As mentioned in the last quarterly report, two computer programs were being written to enhance the post-classification results. The programs are now completed and functional (see Appendices C & D).

The first program, "MR-CLEAN," (Appendix C) improves the spatial homogenity of the classes by eliminating "noise". This program examines each pixel in the classification file, along with its neighbors (above and below, left and right, and diagonally). The pixel's class is then redefined to be that of the majority of this set. If a particular class, perhaps one associated with long narrow bodies (e.g., rivers), is to be left alone, input to the program will cause that class to be bypassed. This program helps produce more uniform fields having less complicated boundaries, which is quite important when extracting boundaries for pen plots in the TNRIS Geographical Information System (GIS). An example of this capability is shown in figures 13a and 13b.

The second program, "DETECT", (Appendix D) compares two classification maps of the same area and produces a map that reflects temporal change between the two scenes. Each scene is classified and registered separately; however, the same symbol must be used to represent the same class in each scene. The program compares the two

Figure 13a. Classification Display before using MR-CLEAN

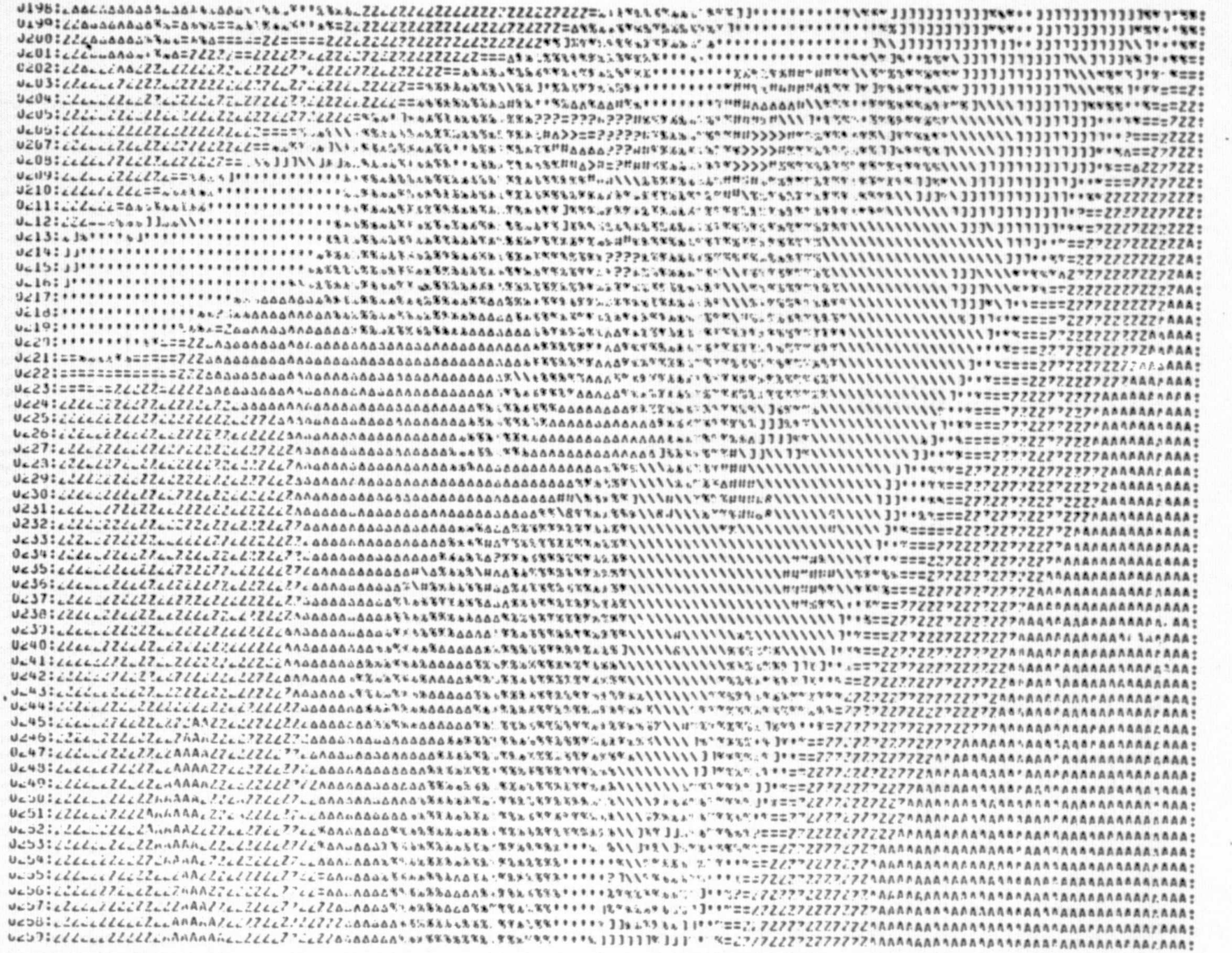


Figure 13b. Classification Display after processing with MR-CLEAN

registered scenes line by line and pixel by pixel. If two corresponding pixels are the same, a blank is printed on the change detection map; if the pixels are different, the symbol from the first scene is printed and represents a change. Each scene is registered using programs from the DAM package, and thus should be registered within a pixel or two accuracy. Offset values may be input to shift the scenes by a few lines or pixels if it is felt necessary to do so for better alignment. An example of this capability is shown in Figure 14a-c.

In addition, a change was made to improve the process of selecting training fields for refinement of some spectral classes. Comparison of the preliminary classification results with aircraft photography and other "ground truth" data is accomplished using the computer-generated display which has been scaled and registered to a 1:24,000 topographic map. The line and sample numbers of pixels on this map no longer relate directly to the line and sample numbers of the original digital tape data. Consequently, when areas of the map are selected for additional statistical analysis (e.g., the need to split one class into two or more subclasses or to eliminate large blocks of unclassified data), the area of interest must first be identified on the scaled/registered map and then translated to the corresponding line and sample numbers on the original data tape for use in the ISOCLS process. This is a difficult task because the printouts from the previous ISOCLS run or from the ELLTAP CLASSIFY routine only cover portions of the full map area and contain scale distortion. The best procedure for accomplishing this correlation

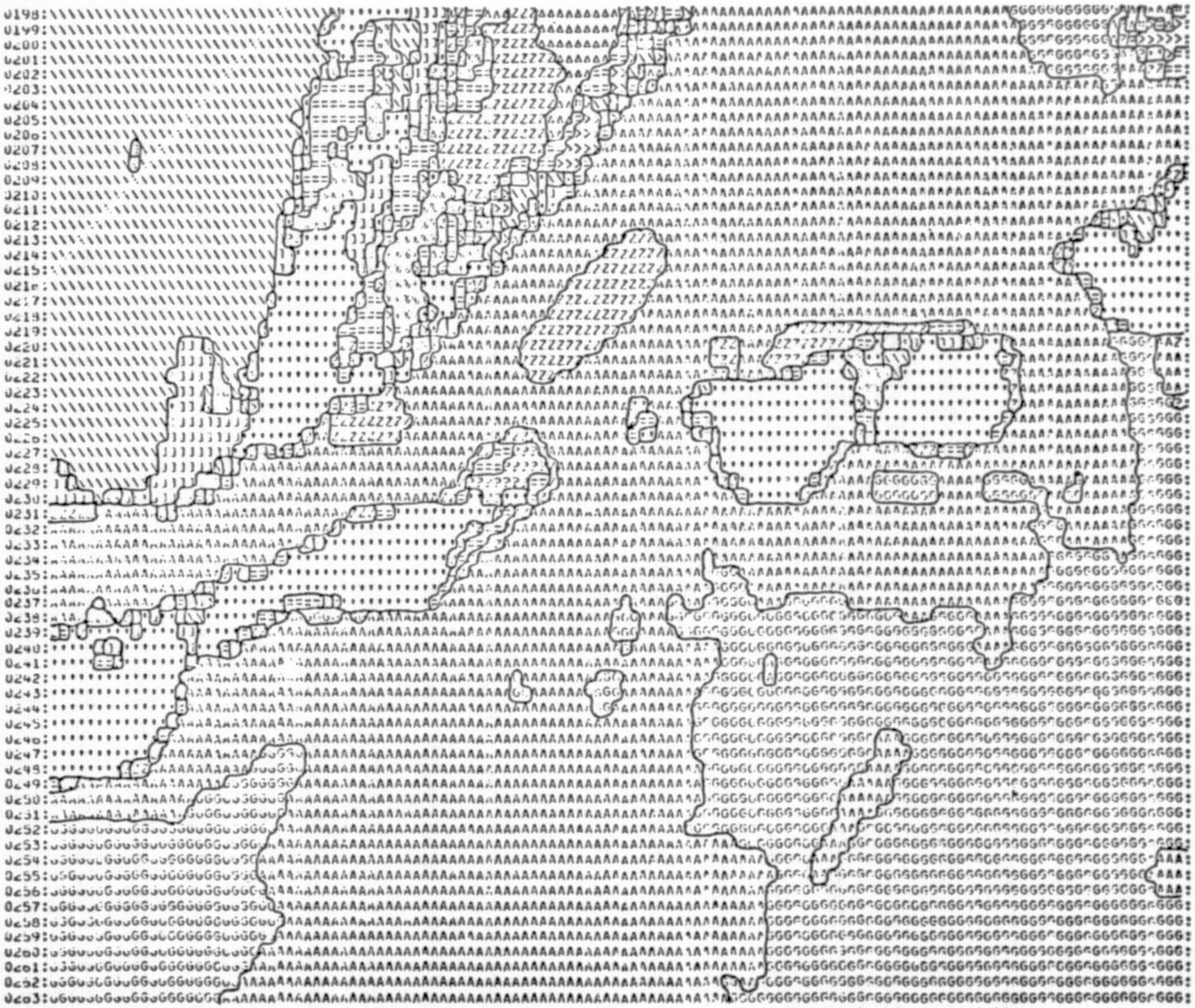


Figure 14a. Part of Site 4 near Port Ingleside on the Corpus Christi Ship Channel on 25 February 1975 (Scene 2034-16202).

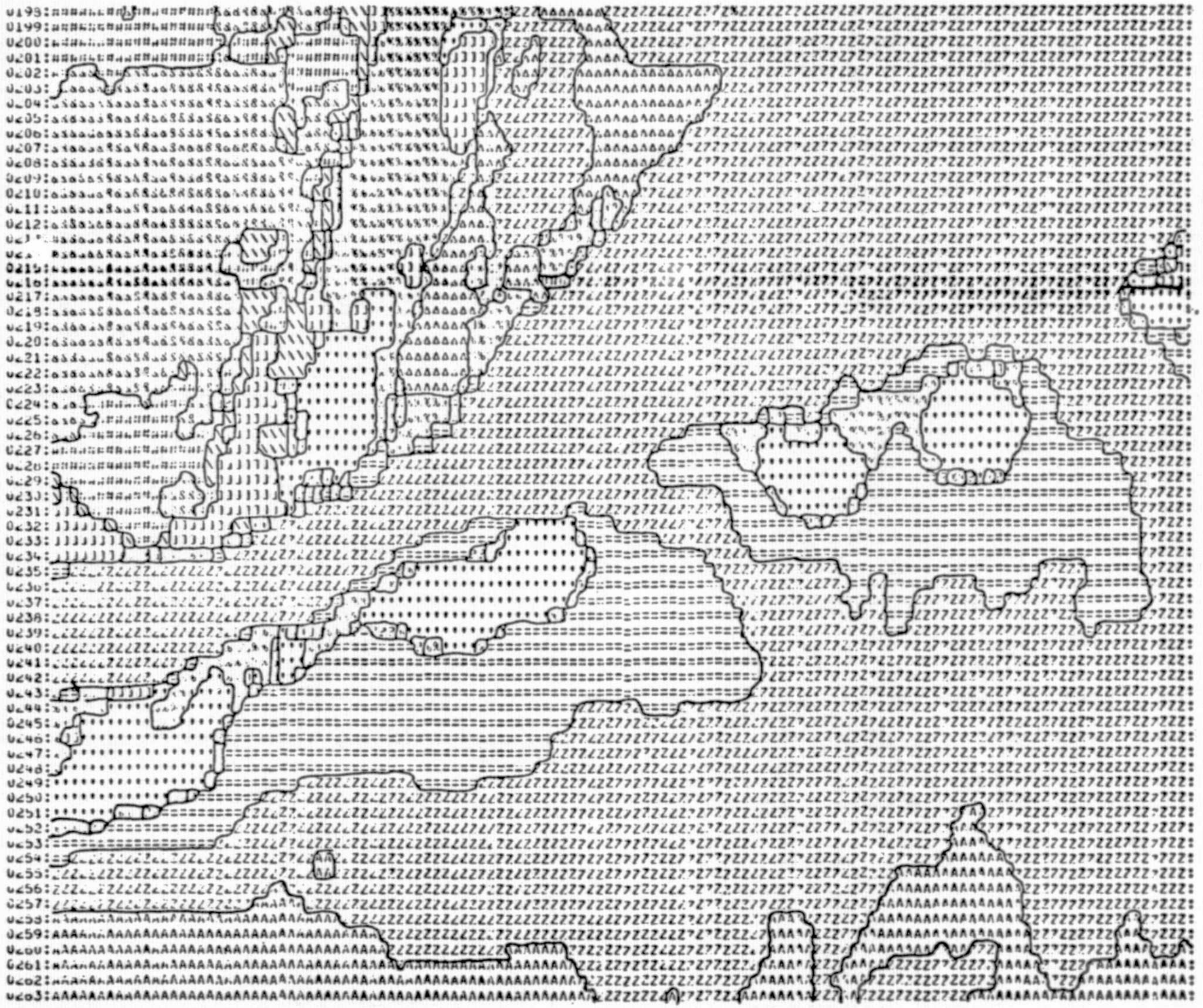


Figure 14b. Same area as Figure 14a, but 6 months later on 10 July 1976 (Scene 3, 5082-16080).

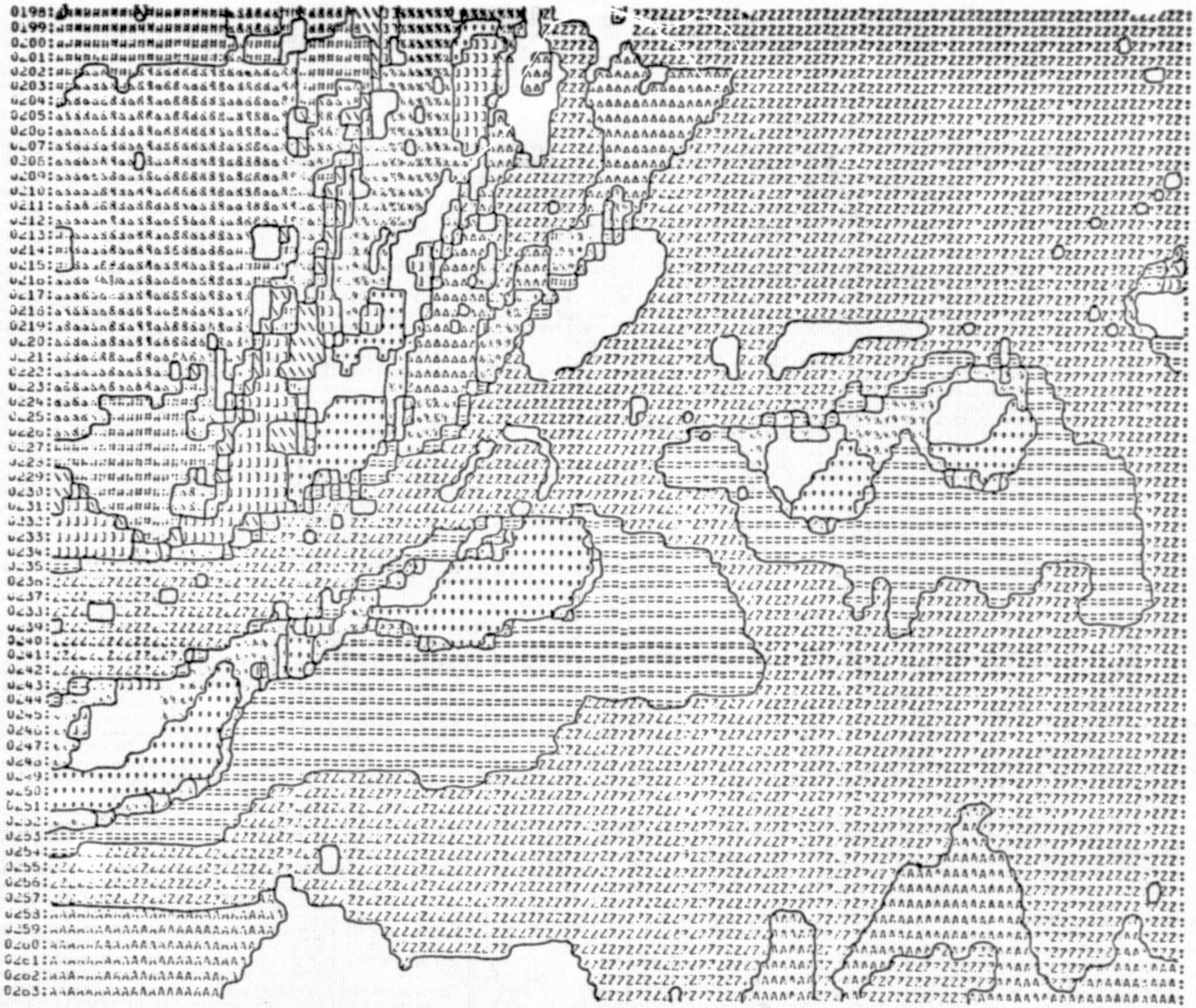


Figure 14c. Change Detection comparing Scene 1 to Scene 3. Blank areas indicate areas of no change, while symbols represent classes present on Scene 3 (that were different on Scene 1).

step has been to use a pre-classification GRAYMAP display of one channel, to determine the exact line and sample numbers. This procedure has been improved by use of the unregistered LARSYS classified printout. This printout contains the same line and sample coordinates as the original data tape and, except for being unscaled and unregistered, contains the same classes as the scaled and registered classification map. Thus the line and sample coordinates from the scaled and registered map can be easily compared to the LARSYS printout to obtain line and sample coordinates for new training fields on the original data tape.

A new version of the DAM package was acquired from the Earth Observation Division of NASA/JSC during this reporting period. The new version retains most of the capabilities of the old program and adds some new features. Some problems in use of the new package were encountered at first, mostly in subroutines supplied by Unavac for use with their computer. However, these have been resolved with help from NASA/JSC. In addition, the changed density file structure in this version necessitated the modification of the multi-class registration program, since the latter relies heavily upon the DAM package. One process from the original DAM package which was excluded from the new version is the PICOUT procedure for establishing the control network. This is a very useful capability and has been incorporated into the new package by TNRIS staff.

3.4.1 Required Improvements in Analysis Procedures and Programs

Several aspects of the computer classification effort need to be improved so that the task of generating map products can be more efficient. Among these are:

(1) ELLTAB TABLE - The current limitation on storage capacity in the Table frequently requires that one or more classes, particularly those with broad standard deviations, be eliminated. This results in an excessive amount of unclassified data. The table capacity has already been expanaded on two occasions but needs still further expansion to adequately handle some of the scenes encountered on Test Site 4 and on sites previously studied.

(2) ELLTAB CLASSIFY - This process is currently limited to to 26 classes and 40 subclasses. While the number of useful classes to be depicted on the final display is generally less than 20, many of these are made up of several subclasses. Again, if subclasses are eliminated, an excessive amount of unclassified data may be obtained.

(3) BATCH PROCESSING - The current procedure requires a series of card decks to be entered into computer operations in a particular order, the output from one process being the input to the next process. This break between runs adds an excessive amount of time to the total runs due to other programs being handled on the computer with equal or higher priority. One action being taken is to assign the more routine tasks to the Computer Center Production Control Unit to accomplish on call (e.g., merging CCT's, printing GRAYMAP's, etc.). Some effort has also been made to group the individual processes

or to enter the data via remote terminal in an attempt to streamline the overall procedure but much more work needs to be done in this area.

Action has been taken to alleviate the various difficulties outlined above to the extent possible. The results will be described in the Final Project Report.

3.5 Program for the Next Reporting Interval

During the period covered by this progress report, an extension was granted through August 1977 to provide ample time for completing the Final Report. An outline for the Final Report follows, with the first draft scheduled for completion during June 1977.

DEVELOPMENT AND APPLICATION OF OPERATIONAL TECHNIQUES FOR THE INVENTORY AND MONITORING OF RESOURCES AND USES FOR THE TEXAS COASTAL ZONE

Title Page (and Abstract)

Preface (and Acknowledgements)

Table of Contents

List of Illustrations

List of Tables

(List of Abbreviations and Symbols-Optional)

1.0 INTRODUCTION

1.1 Objectives (in proposal) and Anticipated Results

1.2 Organization (who did what, roles, specific tasks)

1.3 Test Site Selection and Descriptions

1.4 Summary of Accomplishments

2.0 BACKGROUND

2.1 History of Project (ICNRE, TNRIS, RS Plan, State Goals--NASA)

2.2 "The Guinea Pig" - Coastal Management Requirements in Texas (Federal and State Laws, GLO needs, Problems)

3.0 METHODS AND APPROACH (philosophy mostly, or why and how)

3.1 Centralized RS Data Acquisition and Data Library Service

3.2 Landsat Data Analysis Techniques - two options

3.2.1 Image Interpretation

3.2.2 Computer-assisted Analysis

3.3 Ground Truth and Verification of Analysis (role of TPWD studies, field trips, coastal atlas update, photography)

3.4 The Demonstration and Evaluation of Analysis Techniques (methodology)

3.4.1 Demonstration Objectives

3.4.2 Accuracy of Data Analysis

3.4.3 Cost-Savings

3.4.4 Application of Landsat Map Products to Coastal Planning and Management Requirements (selection of information requirements and criteria

3.5 Monitoring System Design (What would be required, and why all we have in nucleus of a Remote Sensing information System include institutional needs)

4.0 LAND COVER AND LAND USE CLASSIFICATION SCHEMES FOR USE WITH LANDSAT DATA

4.1 Objectives (philosophy - trying to use USGS System)

4.2 Land Cover and Land Use Classification Scheme for Use with unenhanced Landsat Imagery

4.3 Land Cover and Land Use Classification Scheme for Use with Landsat CCT's

5.0 IMAGE INTERPRETATION ANALYSIS

5.1 Techniques and Support Capability

5.1.1 Regional Base

5.1.2 Data Acquisition Package

5.1.3 Techniques for Mapping

5.1.4 Techniques for Change Detection (and Special Studies)

5.2 Detailed Test Site Analyses

5.2.1 Overview

5.2.2 Test Site 2

5.2.3 Test Site 3

5.2.4 Test Site 5

5.2.5 Test Site 4 - Demonstration Site

5.2.6 Summary

5.3 Accuracy of Image Interpretation Analyses

5.4 Conclusions

6.0 COMPUTER-ASSISTED ANALYSIS

6.1 Techniques and Support Capability

6.1.1 Data Acquisition Criteria

6.1.2 Techniques for Analysis

6.1.3 Techniques for Change Detection (Special Studies)

6.2 Detailed Test Site Analyses

6.2.1 Overview (Evolution of Techniques and Procedures)

6.2.2 Test Site 3

6.2.3 Test Site 2

6.2.4 Test Site 5

6.2.5 Test Site 4 - Demonstration Site

6.2.6 Summary

6.3 Accuracy of Computer-Assisted Analysis of Site 4

6.4 Conclusions and Recommendations

7.0 COST-SAVINGS ANALYSIS ON DEMONSTRATION MAP PRODUCTS

7.1 Introduction

7.2 Costs of Landsat Map Products

7.3 Costs of BEG Environmental Geology Map

7.4 Cost-Savings Analysis

7.5 Conclusions

8.0 APPLICATION OF LANDSAT MAP PRODUCTS TO COASTAL PLANNING AND MANAGEMENT REQUIREMENTS

8.1 Coastal Planning and Management Requirements

8.1.1 Requirements in Legislation

8.1.2 GLO Management Activities, 1972-1976

8.1.3 Land Cover and Land Use Information Needs

8.2 Application of Map Products in Test Site 4 - Demonstration Site

8.2.1 Questions and Evaluation Criteria

8.2.2 Image Interpretation Map Products

8.2.3 Computer-Assisted Analysis Map Products

8.2.4 Summary

9.0 COMPARISON AND EVALUATION OF ANALYSIS TECHNIQUES AND PRODUCTS (include comparison with results in literature and proposed combined technique)

9.1 Accuracy

9.2 Cost

9.3 Application

10.0 SIGNIFICANT RESULTS

11.0 PUBLICATIONS

12.0 RECOMMENDATIONS

REFERENCES

APPENDICES

4.0 SIGNIFICANT RESULTS

Four Landsat scenes were analysed for the Harbor Island Area Test Site to produce land cover and land use maps using both image interpretation and computer-assisted techniques. When evaluated against aerial photography, the mean "accuracy" for three scenes was 84% for the image interpretation products, and 62% for the computer-assisted classification maps. Analysis of the fourth scene was not completed using the image interpretation technique, because of a poor quality, false color composite, but was available from the computer technique. Preliminary results indicate that these Landsat products can be applied to a variety of planning and management activities in the Texas Coastal Zone. For example, computer-derived land/water maps can be used with tide gage data to estimate the locations of shoreline boundaries for management purposes. Also, Landsat images can be used to monitor existing spoil areas and to evaluate proposed sites for the deposition of dredged materials along navigation channels.

5.0 PUBLICATIONS

On February 28, 1977, a talk was given by Peggy Harwood at the Annual Meeting of the American Society of Photogrammetry in Washington, D.C., that was based on part of this investigation. Information included in the talk was covered in sections 3.2.1 through 3.2.5 of this progress report. It is anticipated that the paper, represented by the following abstract, will be submitted to the Journal of the American Society of Photogrammetry this summer:

ABSTRACT

LANDSAT CLASSIFICATION PRODUCTS APPLIED TO INVENTORYING AND MONITORING TEXAS COASTAL RESOURCES

by Peggy Harwood[1], Robert J. Finley[2], Samuel McCulloch[3], and John A. Schell[4]

Over 4 million acres of Coastal Public Lands occur beneath and adjacent to Texas bays and the Gulf of Mexico, within a coastal zone 50 miles wide by 365 miles long. State planning and management of Coastal Public Lands requires 1) continuous monitoring of wetlands, 2) current land use/land cover information along bay margins and ship channels in the vicinity of fast-growing urban and industrial centers, 3) information on changes in the area of tidal and storm flooding along shorelines where subsidence, erosion or accretion are occuring.

A land use/land cover classification scheme was developed for Landsat products around coastal inventory requirements emphasizing wetlands, land use, bay systems, beaches and dunes. Most categories correlated with Levels I and II in use by the U.S. Geological Survey, although some Level III categories were required. Image Interpretation and digital processing products, generated for the Harbor Island area, near Corpus Christi, Texas, indicate that 1) scaled and registered, land/water printer maps provide supportive information on the data, and 2) land use/land cover classification maps from four successive Landsat scenes, between 1972 and 1976, document historical changes in area and type of land cover categories due to channel dredging, industrial expansion and residential site development. These results indicate that Landsat products are a viable tool to support the management of Texas Coastal Public Lands.

1. General Land Office, Austin, Texas 78701
2. Bureau of Economic Geology, The University of Texas at Austin, 78712
3. Texas Natural Resources Information System, P.O. Box 13087, Austin, Texas, 78711
4. Remote Sensing Center, Texas A&M University, College Station, Texas 77843

6.0 RECOMMENDATIONS

7.0 FUNDS EXPENDED

The Progress Report covers three periods; June through August, September through November, and December through February 1977. The vouchers submitted to NASA have been for reimbursement of expenses through December 1976 only, therefore, we will be submitting a voucher for expenses for January and February for which this report does not reflect.

Reimbursement from NASA during this reporting period to the Contractor (GLO) and the Subcontractors (BEG, TPWD, TWDB, and Consultants) is as follows:

General Land Office	$16,636.71
Bureau of Economic Geology	35,855.65
Texas Parks and Wildlife Department	7,556.36
Texas Water Development Board	8,439.00
Consultants	6,063.92

The cummulative total expenditures reimbursed during the three quarters is $74,551.64. The balance of this contract is now $12,304.83.

8.0 DATA USE AS OF FEBRUARY 28, 1977

	IMAGERY Account #23790 Amount	CCT Account #GB3790 Amount	AIRCRAFT Account #GW3790 Amount
Value of Data Allowed	$2,900.00	$5,400.00	$9,588.00
Value Ordered	$1,909.00	$2,000.00	$9,564.00
Value Received	$1,909.00	$2,000.00	$9,564.00
BALANCE	$ 991.00	$3,400.00	$ 24.00

9.0 AIRCRAFT DATA

All NASA aircraft data flown for this investigation continues to be used in a qualitative evaluation of map unit classification in sites 2, 3 and 5. The 1:40,000 color infrared photography (October 1975) has been used extensively for the planning of field work and preliminary checking of results in Test Site 4.

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APPENDIX A

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5 FOR LANDSAT INVESTIGATION #23790

APPENDIX A

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5

FOR LANDSAT INVESTIGATION #23790

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 2:			
	Summer: June - August			
2	1037 - 16251	08/29/72	20%	8888
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	Fall: Sept. - Nov.			
2	1073 - 16251	10/04/72	30%	8888
	Winter: Dec. - Feb.			
2	1217 - 16261	02/25/73	20%	8888
2	1505 - 16230	12/10/73	00%	2822
2	1901 - 16110	01/10/75	10%	8808
2, 4	2375 - 16112	02/01/76	00%	
2	1576 - 16152	02/19/74	00%	8888
	Spring: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
2, 4	1289 - 16261	05/08/73	00%	8888
2	2051 - 16140	03/14/75	00%	8855
2	5027 - 16050	05/16/75	10%	5588

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 3:			
	Summer: June - Aug.			
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
	1038 - 16305	08/30/72	20%	8888
	1362 - 16305	08/30/72	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	Fall: Sept. - Nov.			
	1092 - 16312	10/23/72	20%	8888
	1110 - 16313	11/10/72	00%	8888
	1452 - 16291	10/18/73	00%	7828
	Winter: Dec. - Feb.			
2, 4	1146 - 16314	12/16/72	00%	8888
	1164 - 16312	01/03/73	10%	8888
	1182 - 16313	01/21/73	00%	8888
2, 4	2034 - 16200	02/25/75	00%	8888
	2016 - 16200	02/07/75	10%	5888
2	1578 - 16264	02/21/74	10%	8282
	Spring: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
	1289 - 16261	05/08/73	00%	8888
	1236 - 16320	03/16/73	10%	8888

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	1290 - 16315	05/09/73	00%	8888
	1308 - 16314	05/27/73	20%	8888
2, 4	1614 - 16261	03/29/74	10%	8888
	1974 - 16133	03/24/75	00%	8858
2	5028 - 16104	05/17/75	10%	8885
	Test Site 4:			
	Summer: June - Aug.			
2	1326 - 16315	06/14/73	10%	8888
5	1380 - 16311	08/07/73	30%	8883
5	1722 - 16232	07/15/74	30%	8858
5	2501 - 16081	06/06/76	20%	8885
2	1740 - 16225	08/02/74	20%	8888
5	1758 - 16221	08/20/74	20%	8888
2, 4	5082 - 16080	07/10/75	10%	8888
	Fall: Sept. - Nov.			
2, 5	1092 - 16314	10/23/72	10%	8888
5	1110 - 16320	11/10/72	10%	8888
	1452 - 16293	10/18/73	10%	8828
5	1776 - 16212	09/07/74	30%	5588
2	2268 - 16184	10/17/75	00%	5555
	Winter: Dec. - Feb.			
2, 4, 5**	1146 - 16320	12/16/72	20%	8888
5	1164 - 16315	01/03/73	20%	8888
2, 3*	1182 - 16315	01/21/73	00%	8888

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
5	2016 - 16202	02/07/75	00%	5885
2, 4	2034 - 16202	02/25/75	00%	8883
5	2375 - 16112	02/01/76	00%	8588
2, 4	2376 - 16172	02/02/76	00%	8888
	Spring: Mar. - May			
5	1236 - 16323	03/16/73	20%	8888
5	1254 - 16323	04/03/73	10%	8888
5	1290 - 16321	05/09/73	20%	8888
2	5334 - 15523	03/18/76	30%	8888
2	1308 - 16320	05/27/73	10%	8888
2	1974 - 16135	03/24/75	10%	8858
5	5028 - 16111	05/17/75	10%	5588
	Test Site 5:			
	Summer: June - Aug.			
	1362 - 16315	07/20/73	20%	8888
	1380 - 16314	08/07/73	20%	8888
	1722 - 16235	07/15/74	20%	8888
2, 4	1740 - 16231	08/02/74	10%	8888
2	1758 - 16223	08/20/74	10%	8888
	Fall: Sept. - Nov.			
2	1110 - 16322	11/10/72	10%	8888
2	1776 - 16215	09/07/74	20%	5855
	1452 - 16300	10/18/73	20%	8888

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Winter: Dec. - Feb.			
2, 4	1182 - 16322	01/21/73	00%	8888
	1506 - 16293	12/11/73	10%	8888
2, 4	2034 - 16205	02/25/75	00%	8888
	Spring: Mar. - May			
	1614 - 16270	03/29/74	20%	8888
	1974 - 16142	03/24/75	10%	8888
	2070 - 16203	04/02/75	20%	8588
2	1290 - 16324	05/09/73	20%	8888

* TAPE COULD NOT BE REPRODUCED BY EDC/Goddard

** SPECIAL COLOR COMPOSITE (BANDS 4, 5, 6) REQUIRED DUE TO POOR BAND 7 QUALITY

ACQUISITION STATUS

1 Imagery on Order

2 Imagery on Hand

3 Tapes on Order

4 Tapes on Hand

5 Selected Products on Hand for Special Study

APPENDIX B

WORK ACCOMPLISHED TO DATE IN THE PRODUCTION OF COMPUTER-GENERATED MAPS FOR EACH SCENE

APPENDIX B

SCENE 1 ANALYSIS

Task Problems - Establishment of the DAM control network proved to be of some difficulty due to the lack of adequate control points in key areas of the CCT. As a result of this problem, slightly more than normal time was required to establish a workable control network. No control points could be selected from CCT 4 due to its offshore location. A summary of the control network parameters is contained in Table B-1.

Table B-1 Summary of Control Network Parameters for Registration of Site 4 Landsat Scenes

	Scene No.			
	1	2	3	4
Total Control Points	7	7	9	8
RMS (meters)	60	111	95	82
% of Scene Covered	37	32.5	42.6	39

Another problem, related to the Detection and Mapping (DAM) Package, was in the area of final registration. There were previously no provisions in the DAM package to deal with an additional 24 data columns found in Landsat 2 digital data. The DAM software was modified by TNRIS staff to accept the additional columns.

Training Areas - Through the use of aerial photography and site related grayscale printer maps, three ISOCLS training areas were initially selected for clustering. Two additional training

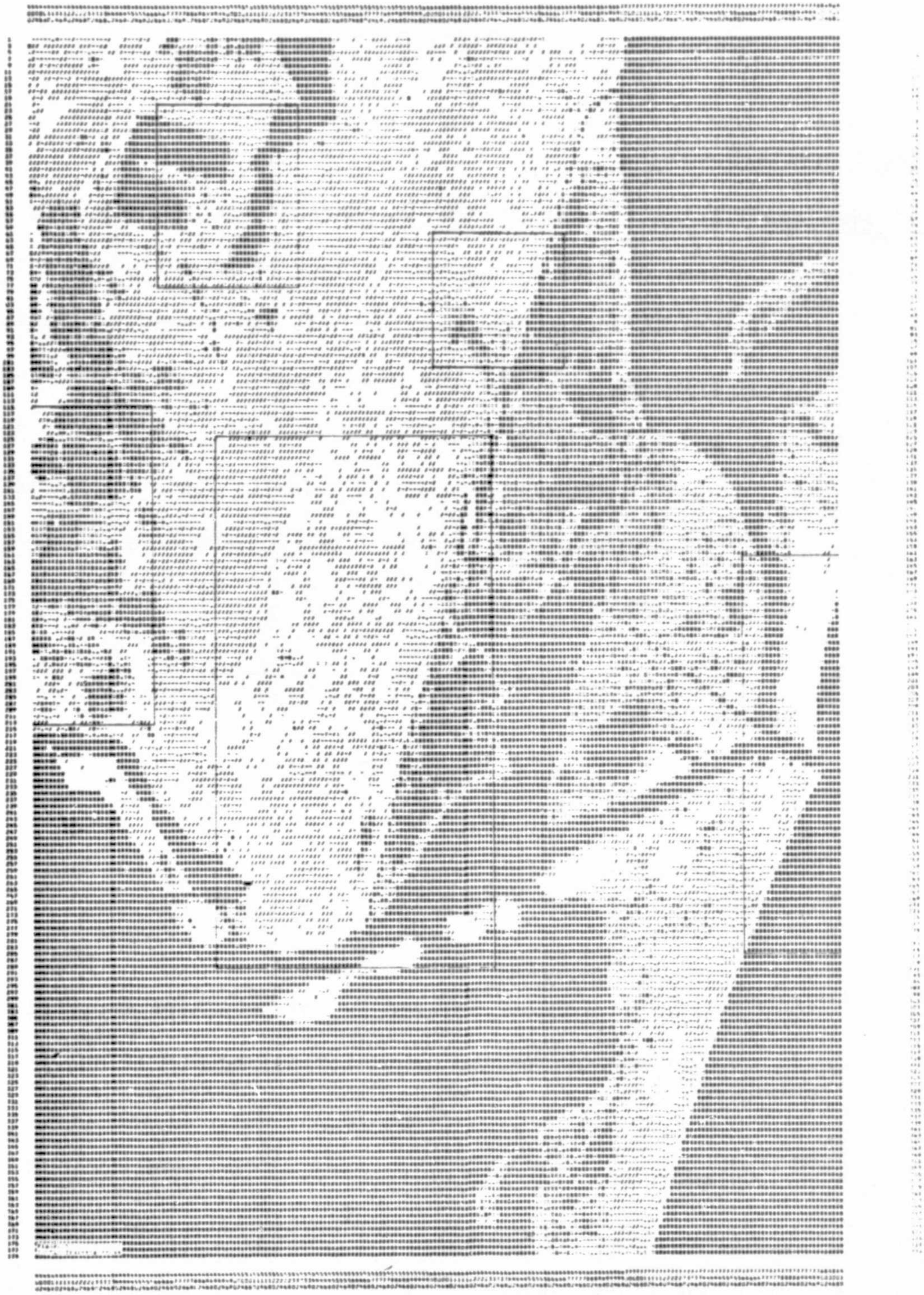

Figure 5. ISOCLS Training Areas

areas were later added as a result of refinement efforts. All subsequent evaluations utilized the five training areas established at this time. (Figure B-1)

Correlation - Examination of the preliminary classification map indicated the need for additional refinement. These steps are summarized as follows:

ISOCLS - Performed on 3 small areas containing pixels of questionable classification, selected from the Scene 1 scale register preliminary display.

ELLTAB TABLE - Statistics for 4 new clusters, generated by the refinement ISOCLS run, were added to those statistics generated by the first ISOCLS. The number of classes was increased from 29 to 33.

HGROUP - A new HGROUP display/chart was required to reflect the 33 classes.

ELLTAB CLASSIFY - Classification was performed on 33 subclasses grouped into 24 classes.

SCALE REGISTER - Certain subclasses with similar statistics, and observed to be of similar makeup, were displayed by one symbol and therefore depicted as a single class. The final scaled and registered display contained 12 classes combined from a total of 33 subclasses. The display covered an area of four USGS 7 1/2' topographic maps: (1) Port Aransas, (2) Aransas Pass, (3) Port Ingleside, (4) and Estes.

SCENE 2 ANALYSIS

Task Problems - Again the establishment of the control network was difficult due to a lack of good control points. CCT 4 consisted of Gulf water and there were no suitable control points in the lower left portion of the scene. A new DAM package (DAM-7605) was used for this particular scene which required minor adjustments. Another problem that required attention occured in the ISOCLS statistics. One class had a mean value of 0.00 in Band 7. This value was arbitrarily changed to 0.01

to allow building the ELLTAB Table which did not accept a zero reading. This change and its influence may be related to the unusually large amount of unclassified water pixels in the bay area of the test site. (Further study is needed to determine the best procedure for handling zero radiance values).

Training Areas -With one minor exception, the number and location of training areas were identical to those utilized for the Scene 1 analysis. A small training area located north of Port Aransas was additionally clustered at this time to rectify the presence of unclassified data not found in the previous test.

Correlation - As a result of correlation, two problems related to classification became apparent. A small area north of Port Aransas and a large amount of water-related data points in the bay failed to be classified.

ISOCLS - Clustering was performed on the previously described unclassified data. The results were evaluated and added to the main group of previously generated training field statistics. A total of 24 clusters were obtained.

ELLTAB TABLE - The table was remade to include preliminary and refinement clustering results (3 additional clusters). A total of 24 clusters were listed and made available for classification purposes.

HGROUP - New HGROUP results reflected a total of 24 classes.

ELLTAB CLASSIFY - The final classification of Scene 2 yielded a total of 24 clusters.

SCALE REGISTER - Through the use of HGROUP results, means plots, and visual examination, similar features were assigned a common symbol. As a result, the original input of 24 classes were reduced and displayed as 10 classes of project interest.

SCENE 3 ANALYSIS

Task Problems - The analysis went very smoothly with no program or procedural setbacks. Some additional time was required because the test area overlapped two CCT's. Thus, two DAM runs and two CLASSIFY runs had to be made.

Training Areas -The areas selected were identical to those of previous scenes.

Correlation - Because of favorable classification results, only minor refinement work was required. This consisted of assigning a common symbol to similar classes in order to display them as one particular type of feature.

ISOCLS - ISOCLS refinement work was not required.

ELLTAB TABLE - The initial table (37 clusters) was retained and no rebuilding with additional statistics was required.

HGROUP - Preliminary HGROUP results were satisfactory.

ELLTAB CLASSIFY - Because of favorable initial results, reclassification was not necessary.

SCALE REGISTER - Classification results consisting of 37 subclasses were reduced and displayed as 10 classes of interest.

SCENE 4 ANALYSIS

Task Problems - The presence of bad scan lines located within a few of the pre-established training fields required slight modification of the training field areas. No other classification problems were encountered.

Training Areas - Training fields were similar to those used in previous tests. Those fields with bad scanner data were slightly reduced in size to avoid detection of erroneous statistical data.

Correlation - The results of correlation efforts indicated that a favorable classification of Scene 4 had been achieved. Only slight symbol combining was necessary.

ISOCLS - No change in the initial statistical results (36 clusters) was required.

ELLTAB TABLE - Increasing the size of the table (36 classes) was not required.

HGROUP - Initial results containing 36 categories was not increased.

ELLTAB CLASSIFY - Preliminary results proved adequate and 36 classes were initially obtained.

SCALE REGISTER - Combining several classes of similar makeup reduced the number of classes displayed to a total of 12.

APPENDIX C

LANDSAT MR-CLEAN

DB0200-DM*LANDSAT.MR-CLEAN

```
      C***PROGRAM MR-CLEAN***
      C
      C***THIS PROGRAM WAS WRITTEN TO HOMOGENIZE LANDSAT CLASSIFICATION
      C   RESULTS BY RECLASSIFYING A PIXEL TO REFLECT THAT OF ITS NEIGHBORS
      C
      C***READ IN CLASSES TO BE LEFT ALONE
            DIMENSION LINE(3,3300),ISCAN(3300),ISYM(30)
            DATA KNT,NUM/1,0/,IN,IOUT/10,11/
          5 READ(5,100,END=15,ERR=10) ISYM(KNT)
        100 FORMAT(A1)
            KNT=KNT+1
            GO TO 5
         10 WRITE(6,105)
        105 FORMAT(1H0,' ERROR READING SYMBOLS')
            STOP
      C***READ FIRST THREE SCAN LINES
         15 KNT=KNT-1
            CALL MRON(2,'M,06,00,00 . ')
            WRITE(6,106)
        106 FORMAT(1H1)
            READ(IN,END=98,ERR=99) NPIX,(LINE(1,I),I=1,NPIX)
            READ(IN,END=98,ERR=99) NPIX,(LINE(2,I),I=1,NPIX)
            READ(IN,END=98,ERR=99) NPIX,(LINE(3,I),I=1,NPIX)
      C***DON'T PROCESS FIRST SCAN LINE OR FIRST OR LAST PIXELS
            WRITE(IOUT) NPIX,(LINE(1,J),J=1,NPIX)
            NUM=NUM+1
            CALL MAP(1)
         16 ISCAN(1)=LINE(2,1)
            ISCAN(NPIX)=LINE(2,NPIX)
            LAST=NPIX-1
      C***PROCESS MIDDLE SCAN LINE, PIXEL BY PIXEL
            DO 90 I=2,LAST
            ISCAN(I)=LINE(2,I)
            IF (KNT.EQ.0) GO TO 25
            DO 20 J=1,KNT
            IF (LINE(2,I)-ISYM(J)) 20,90,20
         20 CONTINUE
         25 N1=0
            N2=0
            N3=0
            N4=0
      C***COUNT NUMBER OF LIKE PIXELS FOR EACH NEIGHBOR
            DO 30 K=1,3
            DO 30 L=1,3
            IF (LINE(K,I+L-2).EQ.LINE(1,I-1)) N1=N1+1
            IF (LINE(K,I+L-2).EQ.LINE(1,I)) N2=N2+1
            IF (LINE(K,I+L-2).EQ.LINE(1,I+1)) N3=N3+1
         30 IF (LINE(K,I+L-2).EQ.LINE(2,I-1)) N4=N4+1
      C***DOES ANY NEIGHBORING CLASS CONTAIN 5 PIXELS OR MORE?
            GO TO (40,40,40,40,45,45,45,45,45),N1
         40 GO TO (50,50,50,50,55,55,55,55,55),N2
         50 GO TO (60,60,60,60,65,65,65,65,65),N3
         60 GO TO (90,90,90,90,75,75,75,75,75),N4
      C***CHANGE PIXEL CLASS
         45 ISCAN(I)=LINE(1,I-1)
            GO TO 90
         55 ISCAN(I)=LINE(1,I)
            GO TO 90
         65 ISCAN(I)=LINE(1,I+1)
            GO TO 90
         75 ISCAN(I)=LINE(2,I-1)
         90 CONTINUE
      C***WRITE THE ALTERED SCAN LINE
            WRITE(IOUT) NPIX,(ISCAN(I),I=1,NPIX)
            NUM=NUM+1
            CALL MAP(2)
      C***SHIFT SCAN LINES UP THE ARRAY
```

```
      DO 95 I=1,2
      DO 95 J=1,NPIX
   95 LINE(I,J)=LINE(I+1,J)
C***READ NEW SCAN LINE AND LOOP
      READ(IN,END=98,ERR=99) NPIX,(LINE(3,I),I=1,NPIX)
      GO TO 16
C***EOF, WRITE LAST SCAN LINE
   98 WRITE(IOUT) NPIX,(LINE(2,I),I=1,NPIX)
      NUM=NUM+1
      CALL MAP(3)
      ENDFILE IOUT
      WRITE(6,110)
  110 FORMAT(1H0,' END OF MR CLEAN')
      CALL MRGN(2,'M,66,06,03 . ')
      STOP
C***ERROR ON READ
   99 WRITE(6,115)
  115 FORMAT(1H0,' ERROR READING INPUT FILE')
      CALL MRGN(2,'M,66,06,03 . ')
      STOP
C
      SUBROUTINE MAP(M)
      LIMIT=MIN0(120,NPIX)
      GO TO (1,2,3),M
    1 WRITE(6,600) NUM,(LINE(1,I),I=1,LIMIT)
      RETURN
    2 WRITE(6,600) NUM,(ISCAN(I),I=1,LIMIT)
      RETURN
    3 WRITE(6,600) NUM,(LINE(2,I),I=1,LIMIT)
      RETURN
  600 FORMAT(1X,I4,1X,120A1)
      END
```

APPENDIX D

LANDSAT DETECT

```
DB0200-DM*LANDSAT.DETECT
      C***PROGRAM DETECT
      C
      C***THIS PROGRAM COMPARES TWO CLASSIFICATION MAPS
      C   OF THE SAME AREA AND NOTES CHANGE BETWEEN THE TWO
      C
      C***INPUT FILES = UNIT 10 AND UNIT 11
      C
            DIMENSION L10(1000),L11(1000),IPRNT(1000)
            DATA LINE,ISAM,NUM/3*0/,IPRNT/1000*6H      /
            INTEGER COLON/':'/,ASTER/'*'/,PLUS/'+'/,CHANGE/'C'/
            CALL MRGN(2,'M,06,00,00 . ')
            WRITE(6,666)
        666 FORMAT(1H1)
      C***READ OFFSET DATA
            READ(5,100,END=20,ERR=90) LINE,ISAM
        100 FORMAT()
            IF (LINE.EQ.0) GO TO 20
            IF (LINE-5) 10,10,5
          5 WRITE(6,66)
         66 FORMAT(' MAXIMUM OFFSET OF 5 LINES HAS BEEN EXCEEDED')
            GO TO 99
      C***FIND STARTING LINE ON UNIT 10
         10 DO 15 I=1,LINE
         15 READ(10,END=86,ERR=90) N10,(L10(J),J=1,N10)
            GO TO 25
      C***READ FILES AND LOOK FOR CHANGE
         20 READ(10,END=86,ERR=90) N10,(L10(I),I=1,N10)
         25 READ(11,END=87,ERR=95) N11,(L11(I),I=1,N11)
            NPIX=MIN0(N10,N11-ISAM)
            ISAM=ISAM-1
            DO 80 I=1,NPIX
            IF (L10(I)-COLON) 30,72,30
         30 IF (L10(I)-ASTER) 35,74,35
         35 IF (L10(I)-PLUS) 40,76,40
         40 IF (L11(I+ISAM)-COLON) 45,72,45
         45 IF (L11(I+ISAM)-ASTER) 50,74,50
         50 IF (L11(I+ISAM)-PLUS) 55,76,55
         55 IF (L10(I)-L11(I+ISAM)) 60,80,60
         60 IPRNT(I)=L11(I+ISAM)
            GO TO 80
         72 IPRNT(I)=COLON
            GO TO 80
         74 IPRNT(I)=ASTER
            GO TO 80
         76 IPRNT(I)=PLUS
         80 CONTINUE
      C***WRITE OUT CHANGE DETECTION LINE AND LOOP
            NUM=NUM+1
            WRITE(6,200) NUM,(IPRNT(I),I=1,125)
        200 FORMAT(1X,I4,1X,125A1)
            DO 85 I=1,1000
         85 IPRNT(I)=6H
            GO TO 20
      C***EOF AND ERROR MESSAGES
         86 WRITE(6,300)
        300 FORMAT(///,' END OF FILE 10')
            GO TO 99
         87 WRITE(6,400)
        400 FORMAT(///,' END OF FILE 11')
            GO TO 99
         90 WRITE(6,500)
        500 FORMAT(///,' ERROR READING FILE 10')
            GO TO 99
         95 WRITE(6,600)
        600 FORMAT(///,' ERROR READING FILE 11')
         99 CALL MRGN(2,'M,06,06,03 . ')
            STOP
            END
```